Accelerating Transport Layer Multipath Packet Scheduling for 5G-ATSSS

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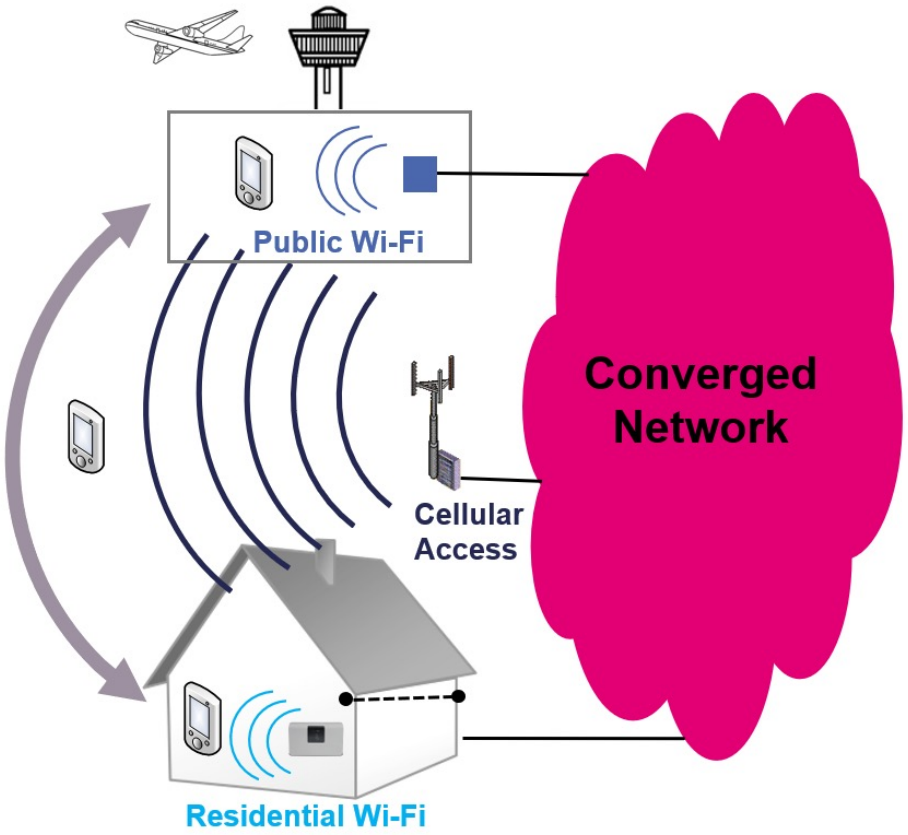
https://multipath-dccp.org

Motivation

- Mobile UE has a multitude of interfaces
  - WiFi, Cellular(3G,4G,5G), Satellite,…
- Current implementations only use one interface for traffic
- Using multiple networks concurrently can have several benefits
  - Increased consistency
  - Higher throughput
  - Higher utilization of low-cost interfaces

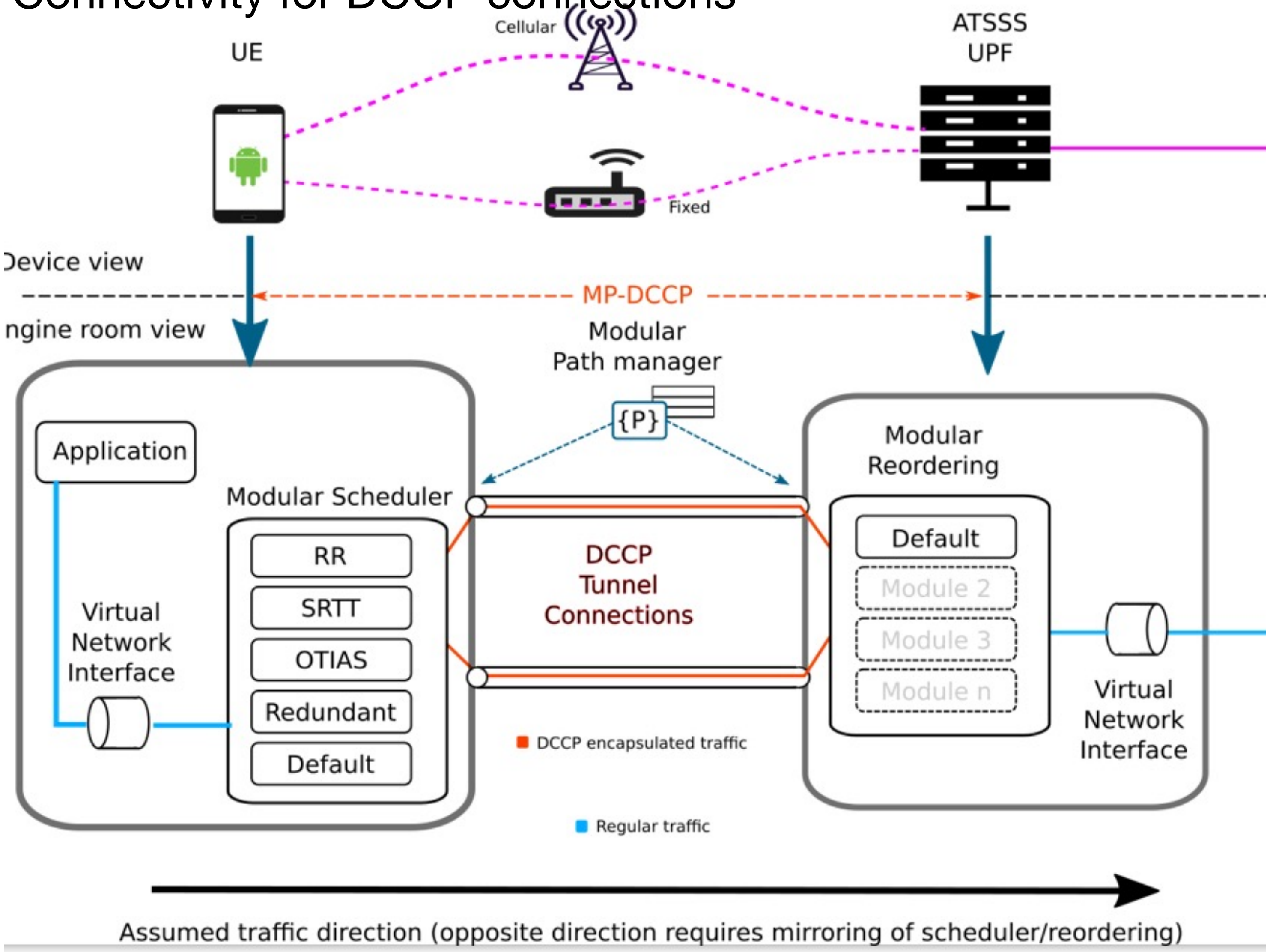


Challenge

- „Preffered“ + secondary path
- Preffered Path Throughput inconsistent and unpredictable, but „lower cost“ for user/network operator
- Aim:
  - Minimize Congestion, Maximize Share of preferred path
  - Keep P4 Implementation possible

MP-DCCP Framework as Enabler for 5GATSSS

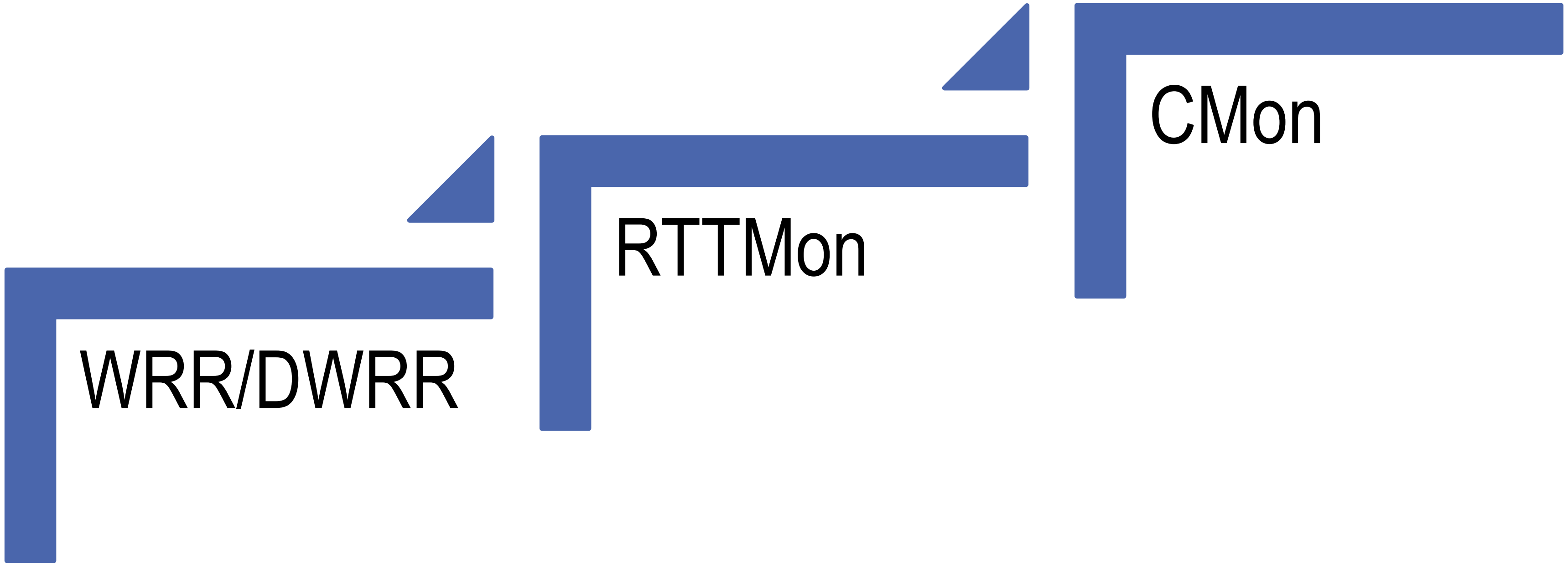
- Enable Multipath Connectivity for DCCP connections



Reordering

- Compensate overall packet scrambling introduced by different path latencies
  →Supports Splitting

Scheduler Implementation in P4

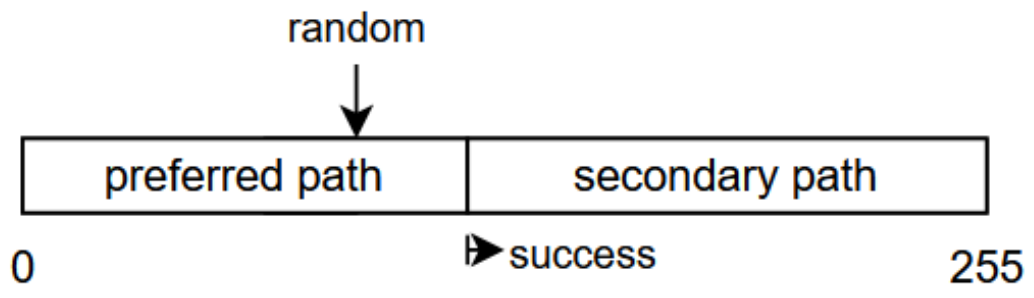


- Rising Complexity of schedulers(tunnel state, scheduling decision)
- Questions
  - Performance Impact?
  - Maximum Complexity?

(Dynamic) Weighted Round Robin Scheduling

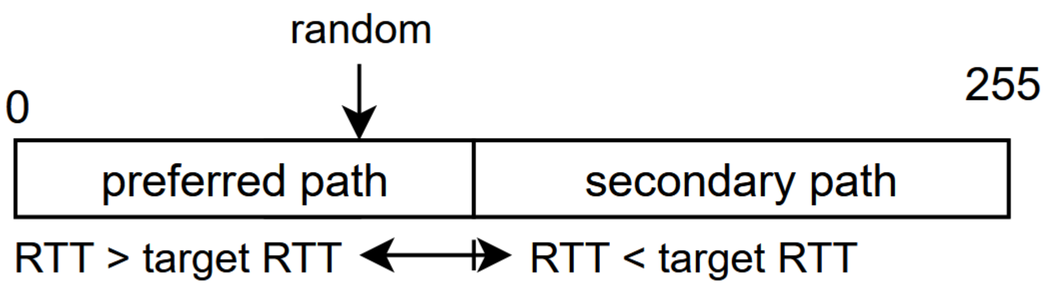
- Compact Weight representation (single 8-bit register)
- Staticor dynamic weights
- Generated random determines path that packet gets scheduled on

- Very lightweight implementation, no additional mutexing necessary
- Weight adjustment on transmittion success/failure



RTT Monitoring Scheduling

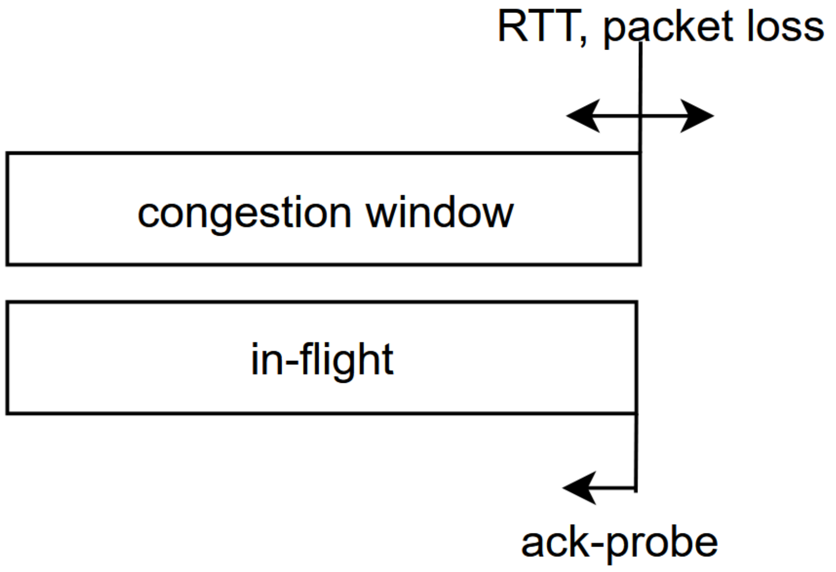
- Weight based scheduling
- Preffered path weight decrease on RTT increase over target RTT
- Regular weight adjustment
- Need for Mutexing
- Complex calculation of Timings



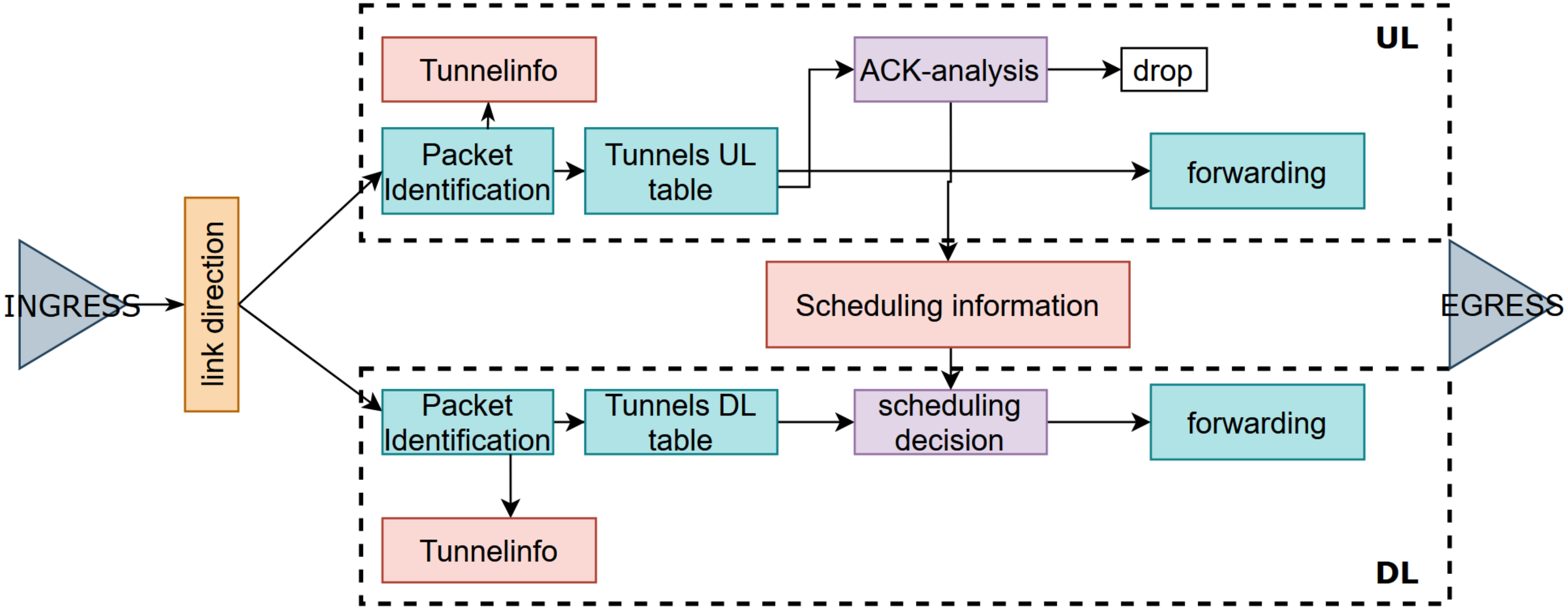

```
targetRTT = (minRTT * 1500) >> 10;
if(targetRTT == minRTT){
    targetRTT = targetRTT + 2;
}
if(shortenedTimestamp > lastScheduling + targetRTT){
    bit<6> currentWeight;
    path_weights.read(currentWeight,meta.index);
    if(currentRTT > targetRTT && currentWeight > 0){
        currentWeight = currentWeight - 1;
    }
    if(currentRTT <= targetRTT && currentWeight < 62){
        currentWeight = currentWeight + 1;
```

Congestion Monitoring Scheduling

- Extend RTTMon with Congestion Window Monitoring
- Not Weight-based
- Additional tunnel state variables (in-flight packets, probing)
- Detects tunnel outages (no relying on received ACKs for tunnel state)
- Extendable to multiple tunnels



Dataplane Pipeline with integrated Scheduler



Scheduling Information

- Central set of registers maintaining tunnel state
- Information used by Schedulers
  - Current RTT
  - Minimum RTT
  - In-flight packets (highest sequence - highest ack)
  - Interval for next scheduling change
- Data gathered on ACK receive

- Array Index per UE and Tunnel
- MP-DCCP Option for RTT measurement

Implementation – Key Challenges

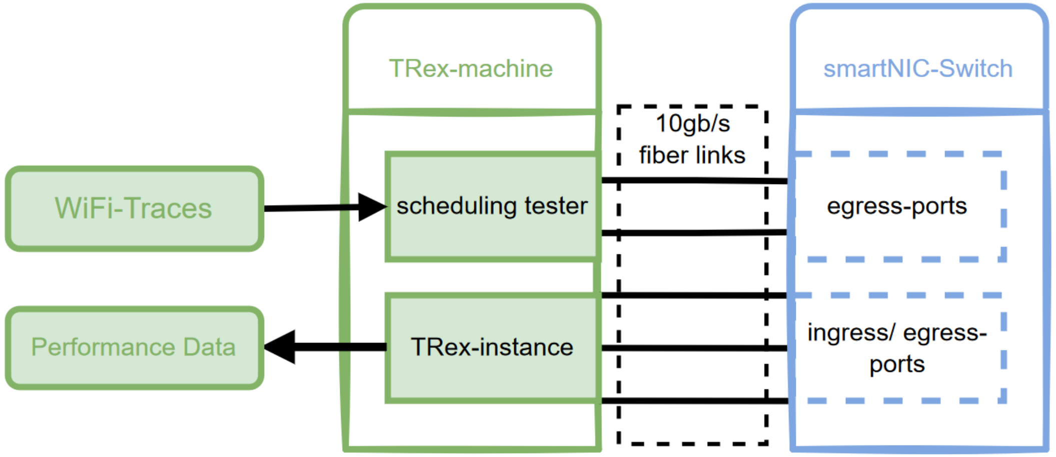
- P4/smartNIC limit available constructs, necessitating some „workarounds“
  - No loops, everything must be done during packet handling
  - Limited division support
    - P4 no support*
    - MicroC only for 32-bit

```
scaledTimestamp = meta.intrinsic_metadata.ingress_global_timestamp;
scaledTimestamp = scaledTimestamp >> 15;
scaledTimestamp = scaledTimestamp - (scaledTimestamp>>2);    //17
scaledTimestamp = scaledTimestamp - (scaledTimestamp>>2);    //19
scaledTimestamp = scaledTimestamp - (scaledTimestamp>>1);    //20
bit<32> shortenedTimestamp = scaledTimestamp[31:0];
```

  - No real number support
    - Ratios and factors must be approximated as integers
  - Mutex support only in MicroC

Performance Evaluation using Testbed

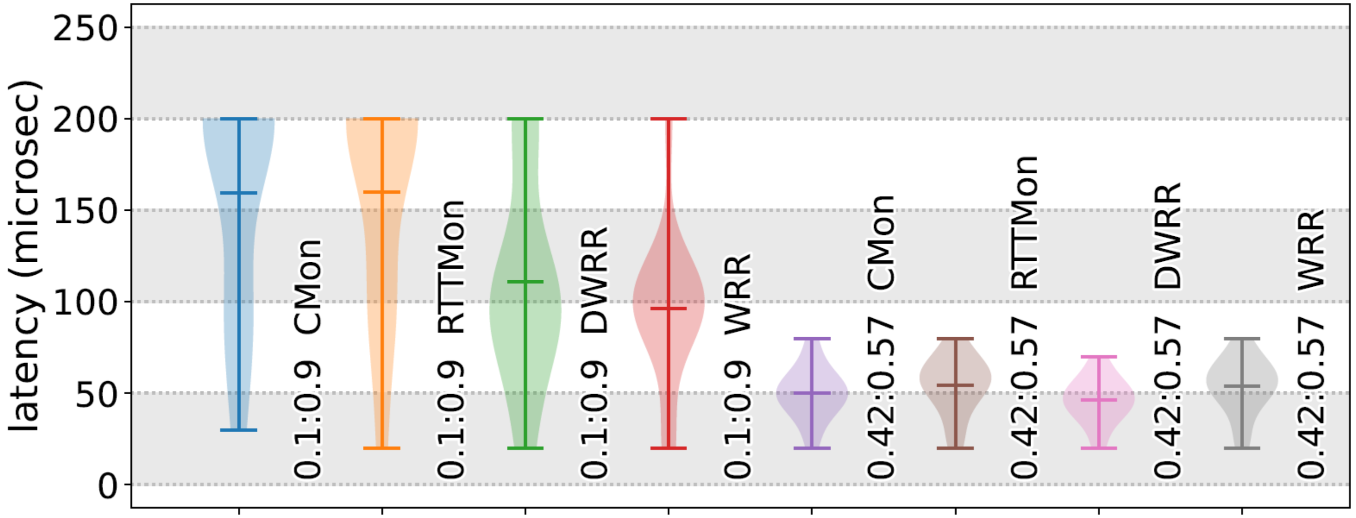
- Trex Traffic Generator
  - 20-core Intel Xeon Silver processor at 3.0GHz, 8 GB RAM. Intel X710 10G SFP+ NIC
  - Trex version v2.93 using DPDK version 21.02.0-rc1, running on Ubuntu 20.04.3 LTS using Linux Kernel 5.4.0-91-generic
- NFP machine (DUT)
  - 20-core Intel Xeon Silver processor at 3.0GHz, 8 GB RAM
  - Netronome Agilio CX NFP4000 processor, 60 (48 PPC, 12 FPC) Processing Cores @800 MHz, 8 threads each 2x40G port split into 8x10 G → 5 microsec base RTT
- Different test cases
  - Scheduling Validation: WiFi-traces for preferred path
  - Performance: Typical 5G - traffic composition



Performance Results

10 kUE
64-1400 B packets
Throughput in mpps

Test	WRR	DWRR	RTTMon	CMon
1:0(512B)	3.0	3.0	2.9	3.0
1:0(1024B)	2.9	2.9	2.8	3.0
0:1(512B)	5.3	5.4	4.5	4.6
0.42:0.57	4.2	4.1	3.7	3.8
0.4:0.6	4.3	4.2	3.8	3.9
0.25:0.75	4.7	4.5	4.1	4.2
0.1:0.9	4.7	4.6	4.2	4.2



Conclusions & Outlook

- P4 supports simple scheduling algorithms
  - Simple Packet analysis, saving tunnel state
  - Challenges due to limited functionality of language and hardware targets
- Scheduler Complexity has limited impact on proxy performance
  - Packet cloning has major performance impact on smartNIC platform

- Integration between user space and data-plane?
- Even more complex schedulers?


thank you
danke
謝謝
ngiyabonga
شكراً جزيلاً
teşekkür ederim
gracias
merci
obrigado
dziękuję
bedankt
спасибо
Баярлалаа
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dank je
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