IETF125 HP-WAN Hackathon Results

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HP-WAN Objectives

- **Success Objectives**
  - *Check HPWAN state of art* for different transport domain technologies.
  - *Indentify methods for end-to-end HPWAN service monitoring* and which IETF performance monitoring and tooling is suitable.
  - *Discuss HPWAN deployment on topologies for public networks and service scenarios* based on the HP-WAN framework.
  - *Test the integration and simulation of the HP-WAN functions*, such as rate negotiation, admission control, traffic scheduling, and resource reservations with distributed signalling (IETF RSVP-TE).
  - *Test the RDMA performance and QUIC-based optimization simulation.*
  - *Discuss requirements for HPWAN service requests*, this includes task and job scheduling and path performance parametres required for HPWAN services.

IETF125 HP-WAN Hackathon Results

- **Hackathon Results**
  - Complete the HPWAN implementation and simulation based on the HP-WAN framework with RSVP-TE extensions and *provide the simulation results and performance comparison based on the traffic transmission with HP-WAN, RSVP-TE and DCQCN*. (Backup page7~12)
  - Complete the QUIC-based Implementations and *provide the simulation results(e.g., packet loss, RTT and average rate)* .(Backup page13~15)
  - Provide the examples for *Lab simulation and CENI testing and the performance results with RDMA*.(Backup page)

IETF125 HP-WAN Hackathon Participants

- **We greatly appreciate the participants to join us! Thanks!**
  - Jie Dong/Kireeti Kompella/Adrian Farrel/Jeffery Zhang/Giovanni Marzot/Daniel Huang/Ran Chen/Ka Zhang

- **Related documents**
  - https://datatracker.ietf.org/doc/draft-kcrh-hpwan-state-of-art/
  - https://datatracker.ietf.org/doc/draft-xhy-hpwan-framework/
  - https://datatracker.ietf.org/doc/draft-xiong-hpwan-signaling-solution/
  - https://datatracker.ietf.org/doc/draft-yx-hpwan-uc-requirements-public-operator/
  - https://datatracker.ietf.org/doc/draft-zhao-hpwan-scenarios-deployment/
- **Repository:**
  - https://github.com/xiongquan1230/IETF125-HP-WAN-Hackathon

HP-WAN Next Steps

- Define the IETF needs to standardize to enable *deployable HPWAN services in multiple domains*.
- Define *high-level HPWAN service model to request HPWAN services* across domains.

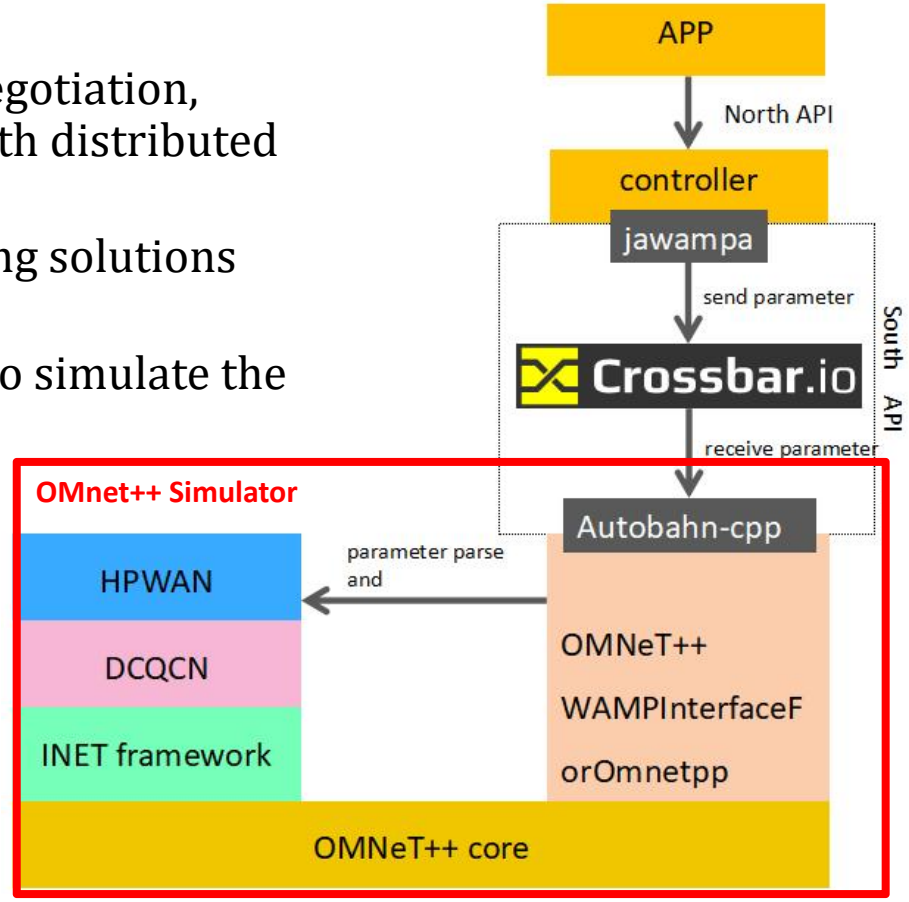
Backup Hackathon Results

HP-WAN RSVP-TE Simulator Design

- **The red box shows the framework and functions design for HP-WAN OMnet++ simulator**
  - design the complicated topologies for public networks and service scenarios specially for HP-WAN framework
  - implement and simulate the HP-WAN functions such as the rate negotiation, admission control, traffic scheduling and resource reservations with distributed signalling
  - to extend the RSVP-TE libraries to implement the HP-WAN signaling solutions through RSVP-TE extensions
  - perform the CC algorithms optimizations (e.g. DCQCN algorithm) to simulate the traffic transmission with negotiated rate

- **Simulation Goals**
  - implement the HP-WAN mechanism with RSVP-TE extensions
  - simulate the traffic transmission with HP-WAN rate-based

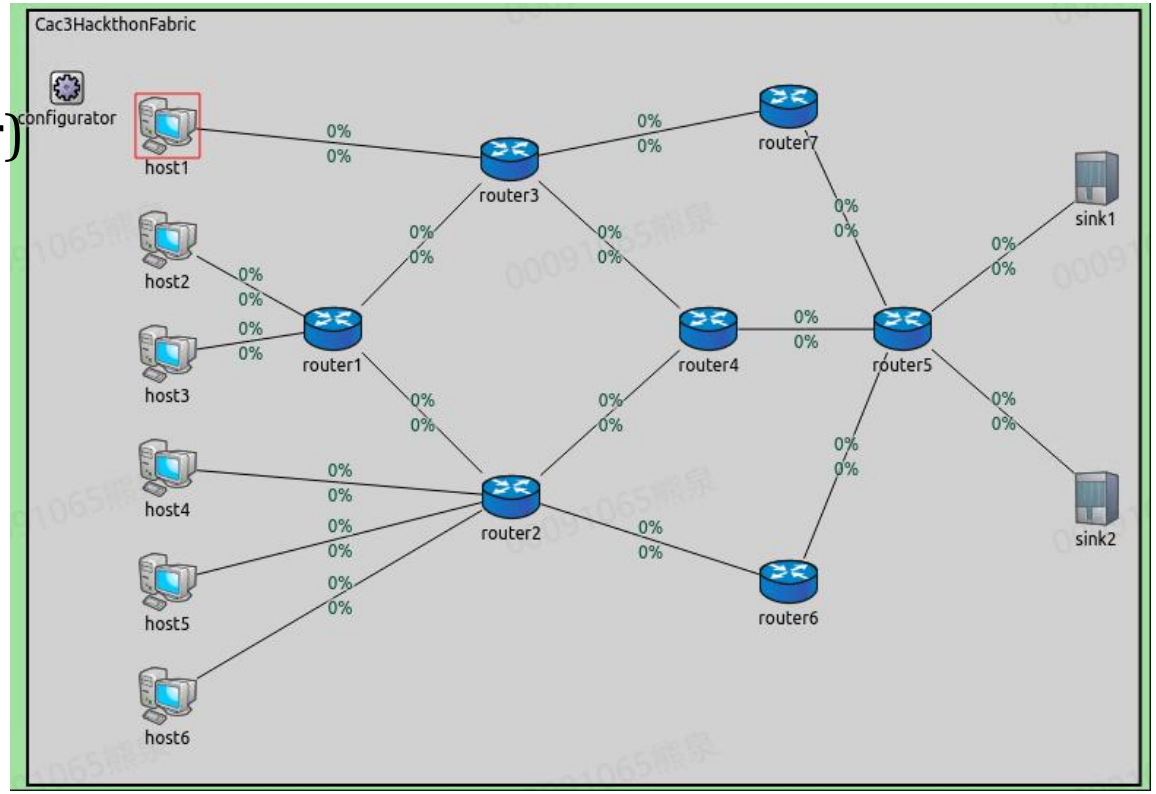
  host-network collaboration
  - performance comparison between HP-WAN, RSVP-TE and DCQCN



Topology and Scenario for HP-WAN Simulator

- **Topology**
  - host 1~6 (as client) and sink 1~2 (as server)
  - router 1~7 in WAN (link bandwidth is 40Gpbs

  and RTT is 10ms or 15ms (about 1000km/1500km)
- **Scenario**
  - host 1~4 send a flow to sink1
  - host 5~6 send a flow to sink2
  - each flow is 100MB
- **Simulation Results**
  - FCT of per-flow or multiple flows
  - Effective throughput at the receiving port



Parameters Configuration for HP-WAN Simulator

Parameters	Value	Description
Data volume for each flow	100MB	massive data transimission
Link bandwidth	40Gbps	
StartTime	0+uniform(0,10us)	introduce a slight disturbance
RTT per link	5ms(between routers), 3us(between host and network)	end-to-end RTT is 10ms or 15ms
transmission direction	Host1~host4->sink1Host5~host6->sink2	
buffer size	<1BDP	50MB
RSVP enable	True/false	
HPWAN enable	True/false	
DCQCN enable	True/false	
mruThreshold	configurable， default 0	trigger the max-rate update
ECN	5KB， 20MB, 0.5%	DCQCN AI step is 400Mbps
Retransmission mechanism	Seltective retransmission	
Out of time	N*RTT(default 5RTT)	

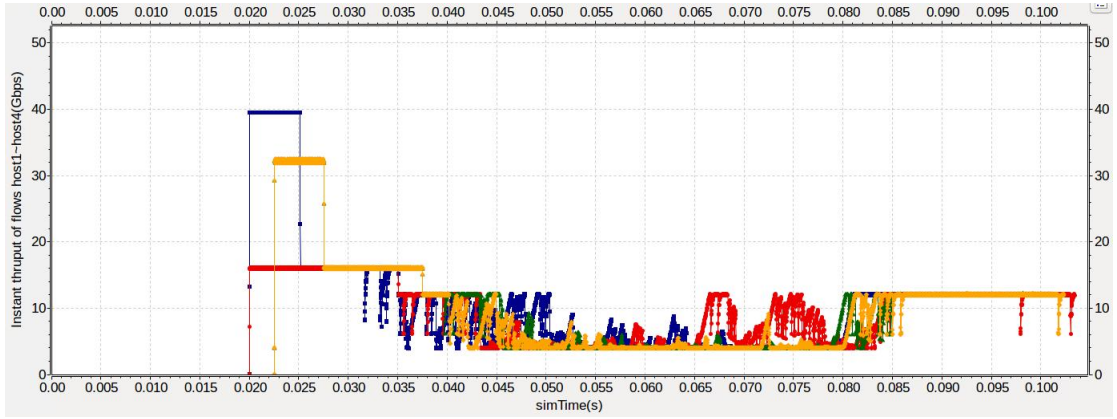
Comparison between HP-WAN,RSVP-TE,DCQCN

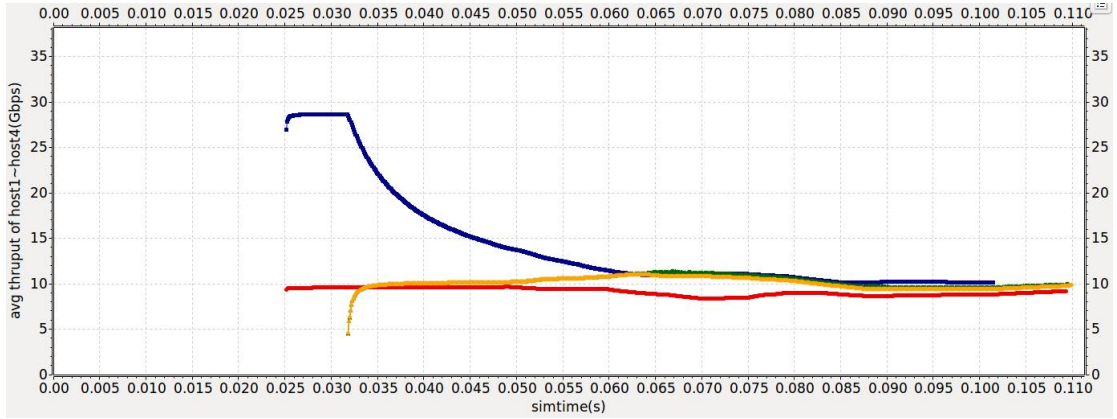
- The result of RSVP signaling with Rate negotiation of minRate and maxRate shows low packet loss and better FCT and FCT deviation, including the admission control and resource reservation based on minRate to guarantee the job completion time, and the maxRate notify to mitigate the congestion.
- The result of RSVP-TE fixed-rate resource reservation shows the worst FCT, as it cannot leverage the "elastic bandwidth" characteristic of data express services to fully utilize network resources.
- The minRate-based admission control mechanism and traditional DCQCN suffer from significant packet loss and retransmissions; even with SR (Selective Retransmission) enabled, performance degradation remains severe.

Mechanism	Solution	Target FCT（ms）	Minimum FCT（ms）	Maximum FCT（ms）	FCT deviation（ms）	Packet loss	Packet retransmission
RSVP signaling with Rate negotiation of minRate and maxRate	RSVP-TE minRate quota-based resource reservation + maxRate notify (update-triggered)	200	81.5	89.5	8	≈0	≈0
	RSVP minRate resource reservation +maxRate notify(congestion-triggered, threshold 10KB)	200	80.7	89.8	9.1	≈0	≈0
RSVP-TE signaling with fixedRate	RSVP-TE resource reservation and fixedRate transmission	200	205	207.5	2.5	≈0	≈0
CAC3 with minRate	RSVP with minRate admission control	200	105.3	123.6	18.8	27456	35422
CC algorithms optimizations	DCQCN	200	112	121.1	9.1	23292	33056

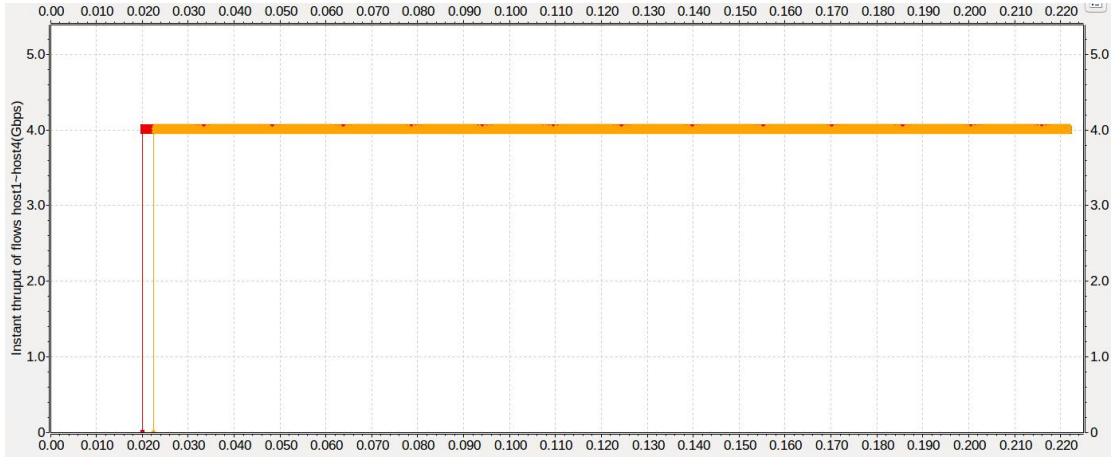
Simulation Results for HP-WAN Simulator

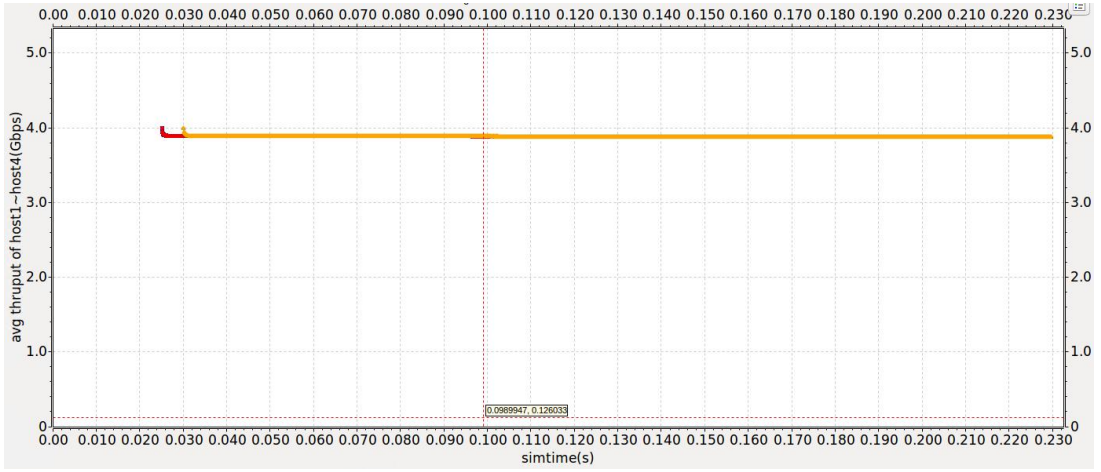
- Throughput results for RSVP signaling with Rate control of minRate and maxRate and dynamic resource quota reservation





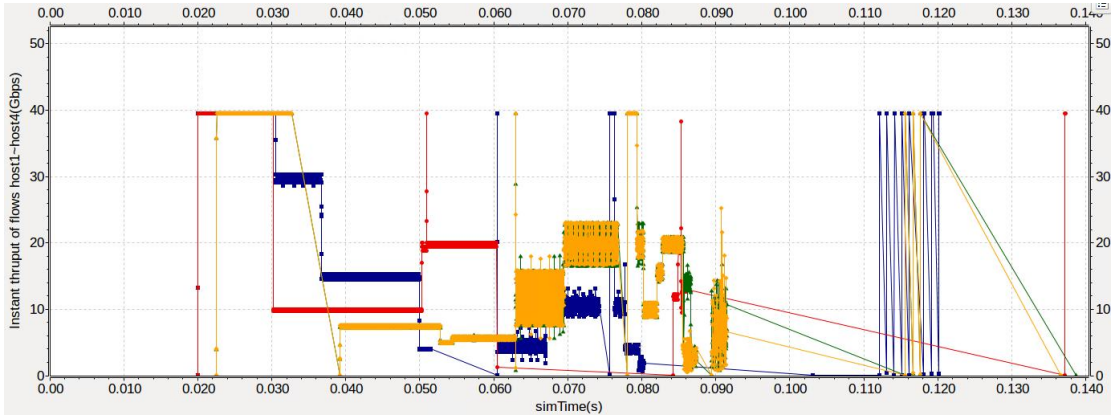
- Throughput results for RSVP signaling for fixedRate and static resource reservation

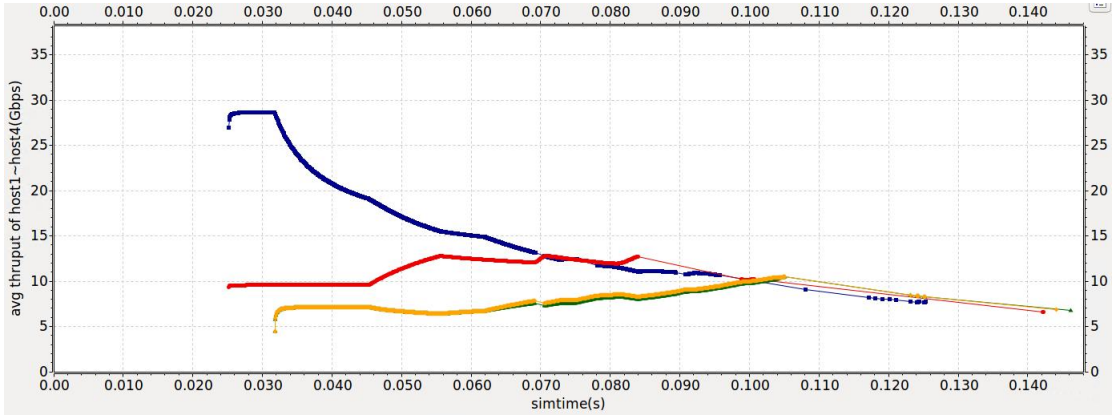




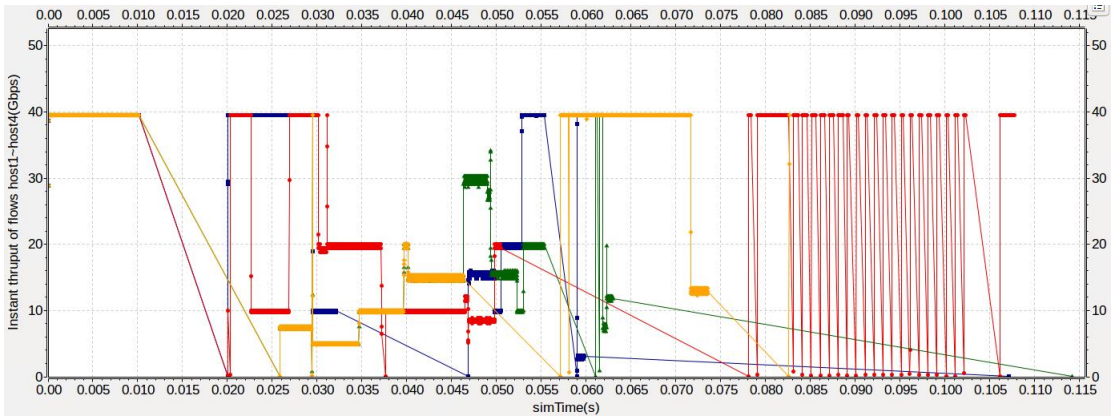
Simulation Results for HP-WAN Simulator (cont)

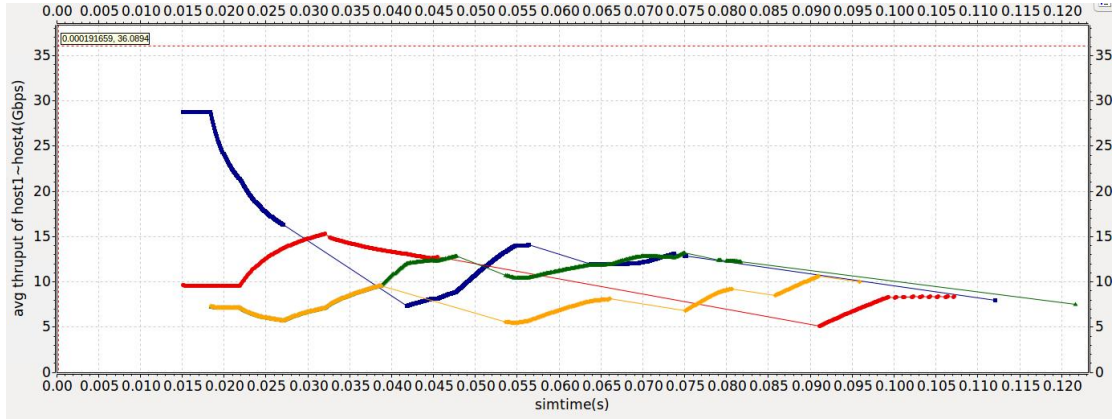
- Throughput results for RSVP signaling with minRate admission control for sharing the resource



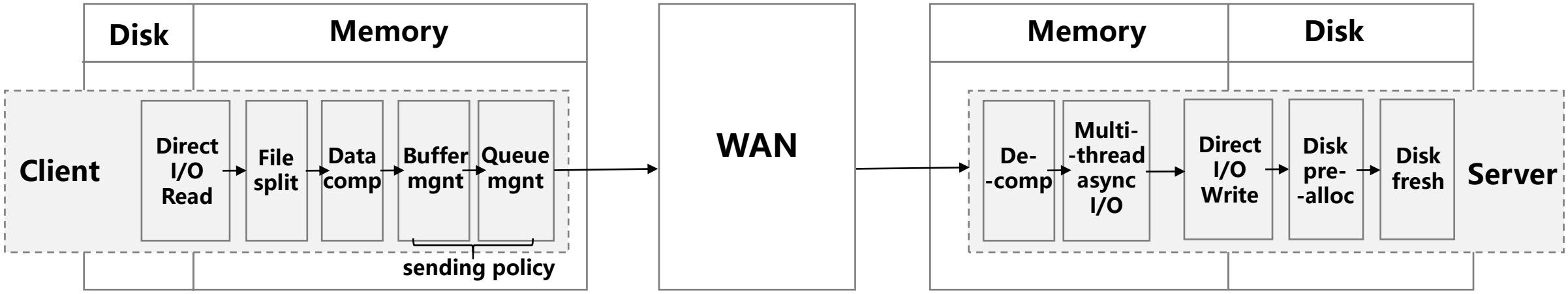


- Throughput results for DCQCN to adjust the sending rates from the host





QUIC-based Implementations



System Optimization

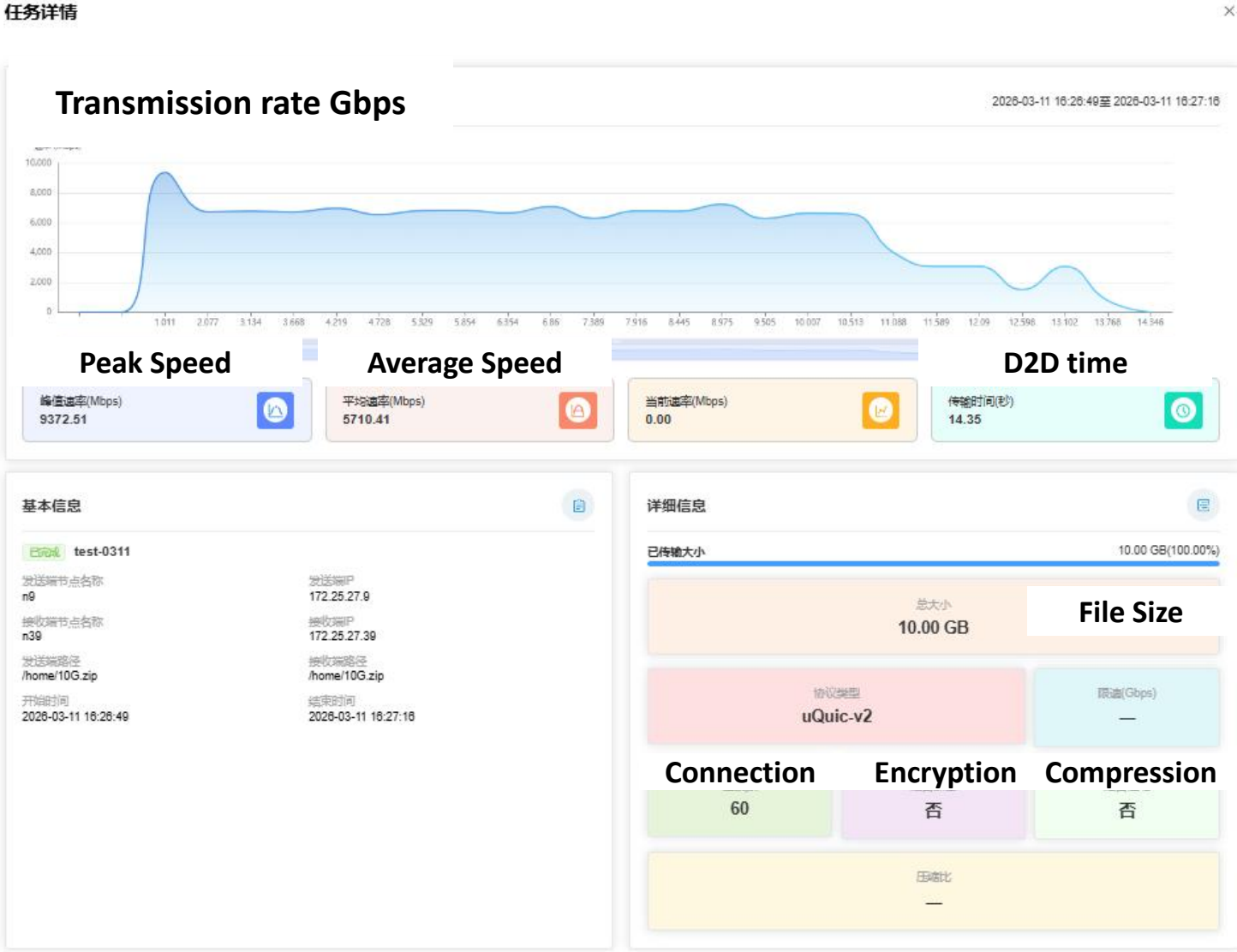
QUIC-based Implementations

- System optimization for QUIC-based Implementations
  - Direct I/O
  - Disk Pre-allocation
  - Sender-side Transmission Policy Optimization
  - Large File Splitting
  - File Compression
  - Multithreaded Asynchronous I/O
- Protocol modifications over standard QUIC
  - **Encryption:** change TLS 1.3 to optional, to reduce the CPU overhead at end server
  - **QoS:** set priorities to flows that require high-performance transmission
  - **Flow control:** per-stream based buffer management
  - **Congestion control:** use dBBR[1] to replace CUBIC for better fairness

1. To be appeared in IWQoS 26

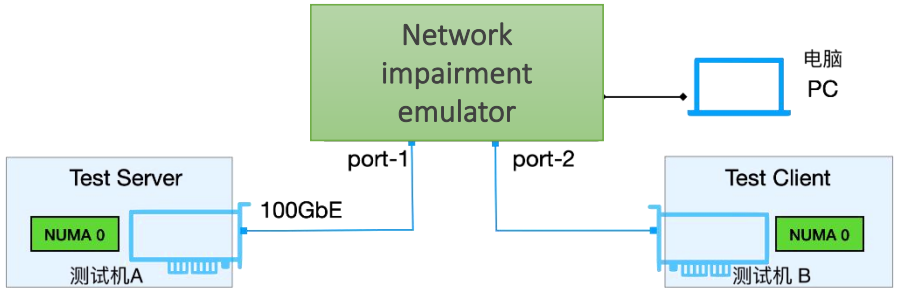
QUIC-based Simulation Results

- File Size: 10 GB
- Link BW: 10Gbps
- Distance: Beijing - Guangzhou
- RTT: ~50ms
- Packet loss rate: ~5%
- Number of Connections: 60
- Disk-to-Disk time: 14.35s
- Average speed: 5.710Gbps
- Peak speed: 9.372Gbps



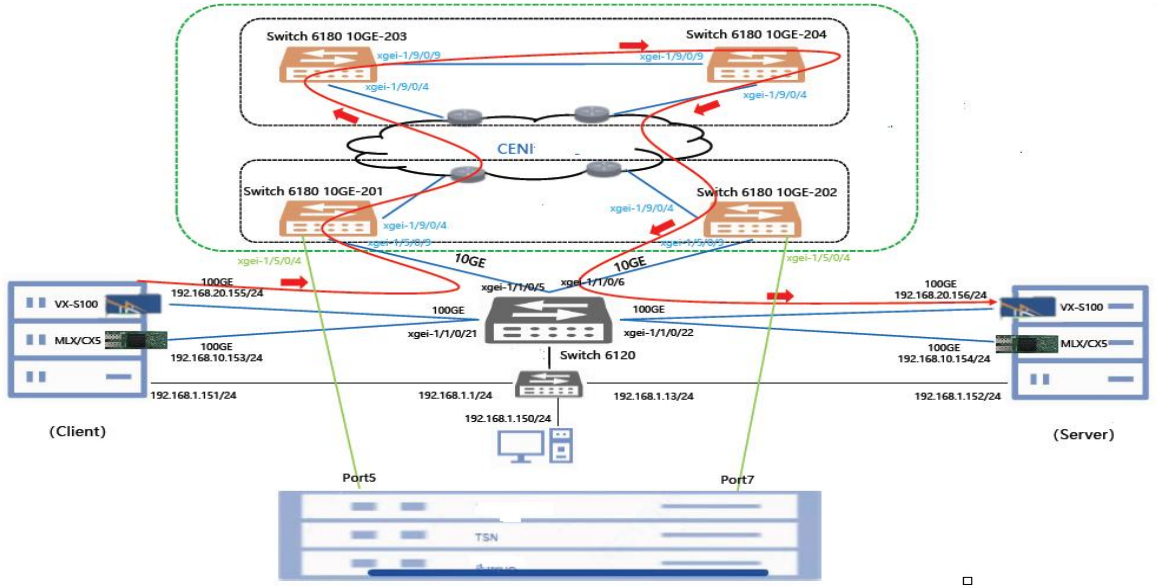
Examples for Lab Simulation and CENI Testing

Lab Simulation



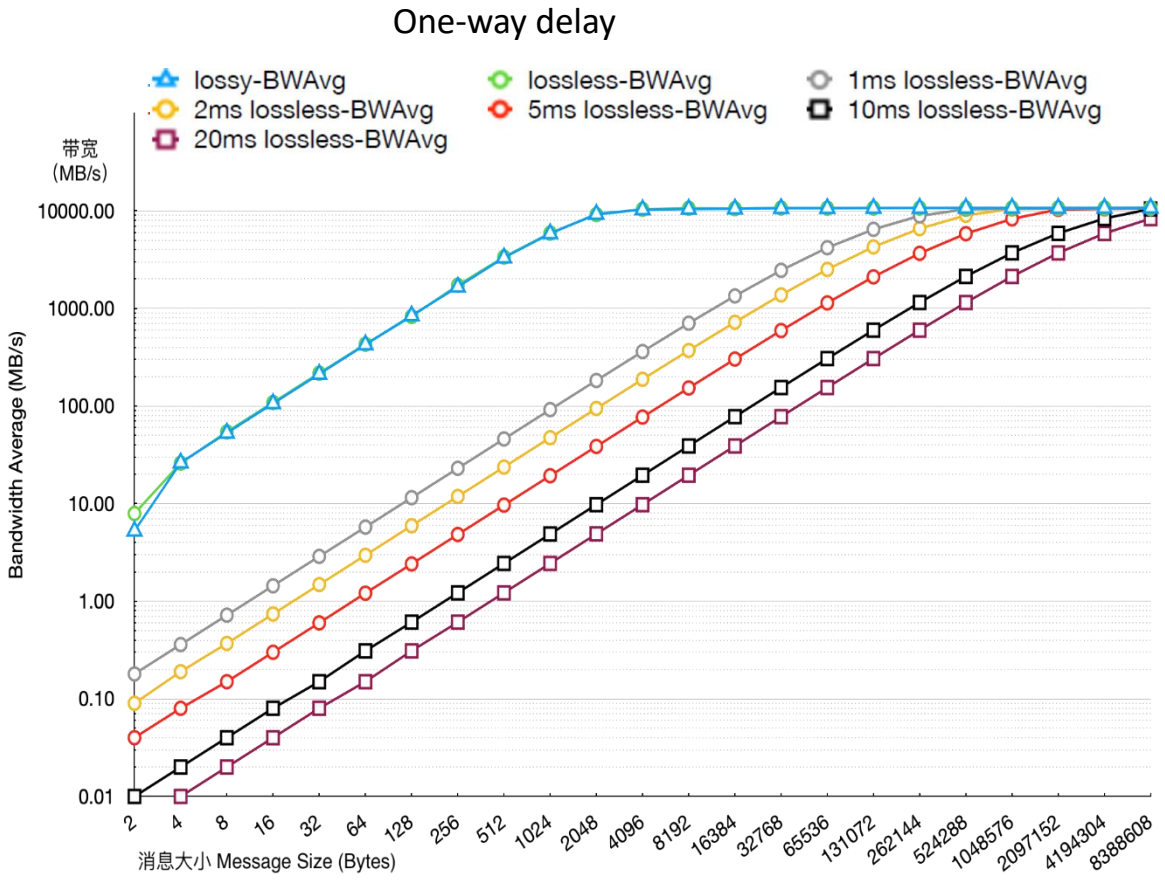
- The lab tests used **network impairment emulator** to simulate:
  - ✓ Variable latency (0-20ms)
  - ✓ Jitter (±0~1ms)
  - ✓ Packet loss ratio (0.001%-0.1%)
- The goal is to test the impact of **deferent latency, jitter, and packet loss combinations** on high-throughput transmission performance(e.g.RDMA).

CENI Testing Topology



- Performed comparative validation on 2000km wide-area deterministic network.
- Attempted to analyze **deterministic performance thresholds** for:
  - ✓ High-throughput transmission
  - ✓ Low-latency RDMA operation

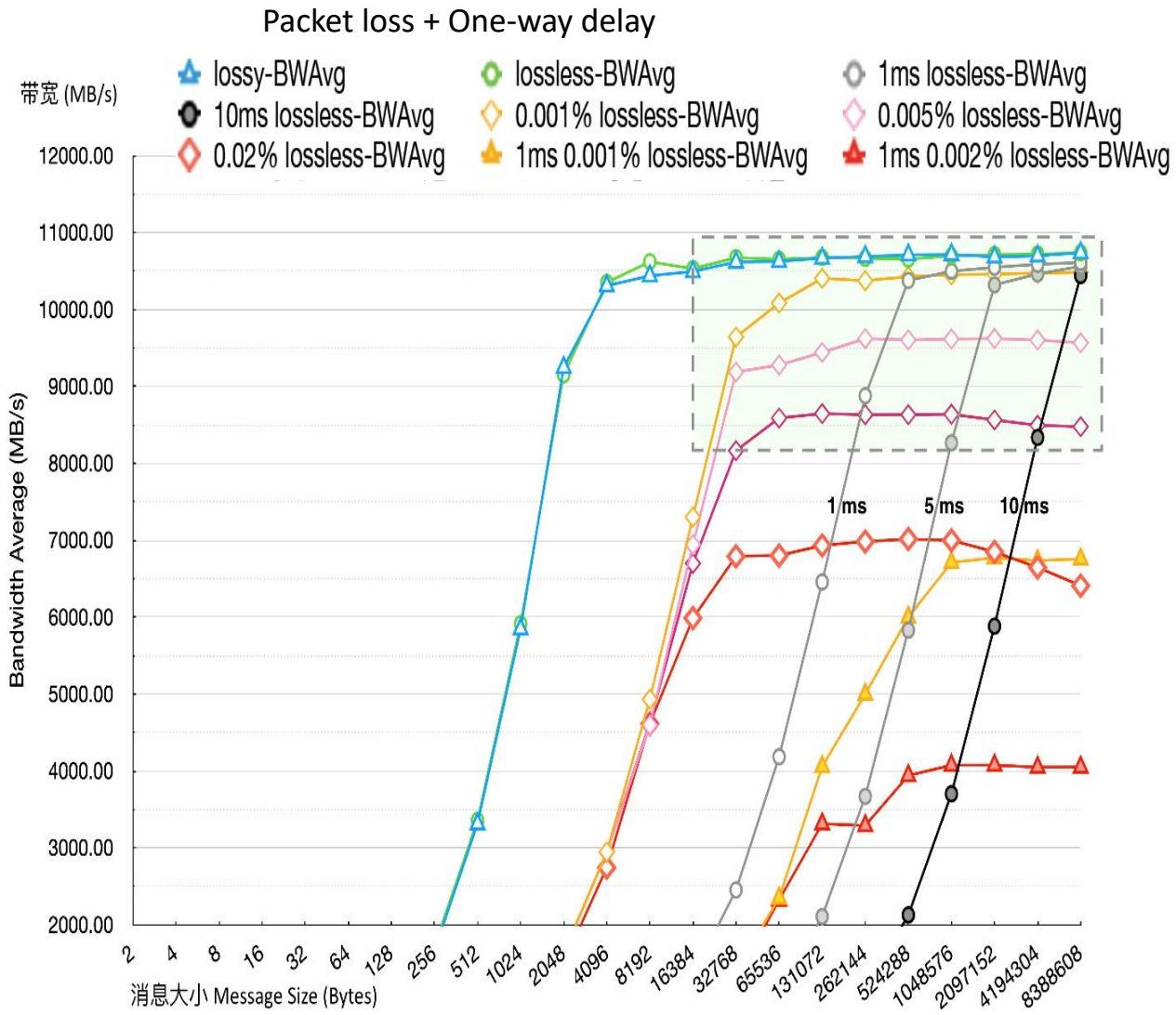
The impact of long distance and latency



RTT latency (ms)	message length (byte)	transmission distance(km)	Throughput (Gbps)
<1	<1 024	<100	>90%@100Gbps
1	≈256 K	100	>90%@100Gbps
2	≈512 K	200	>90%@100Gbps
5	≈1 M	500	>90%@100Gbps
10	≈8 M	1000	>90%@100Gbps

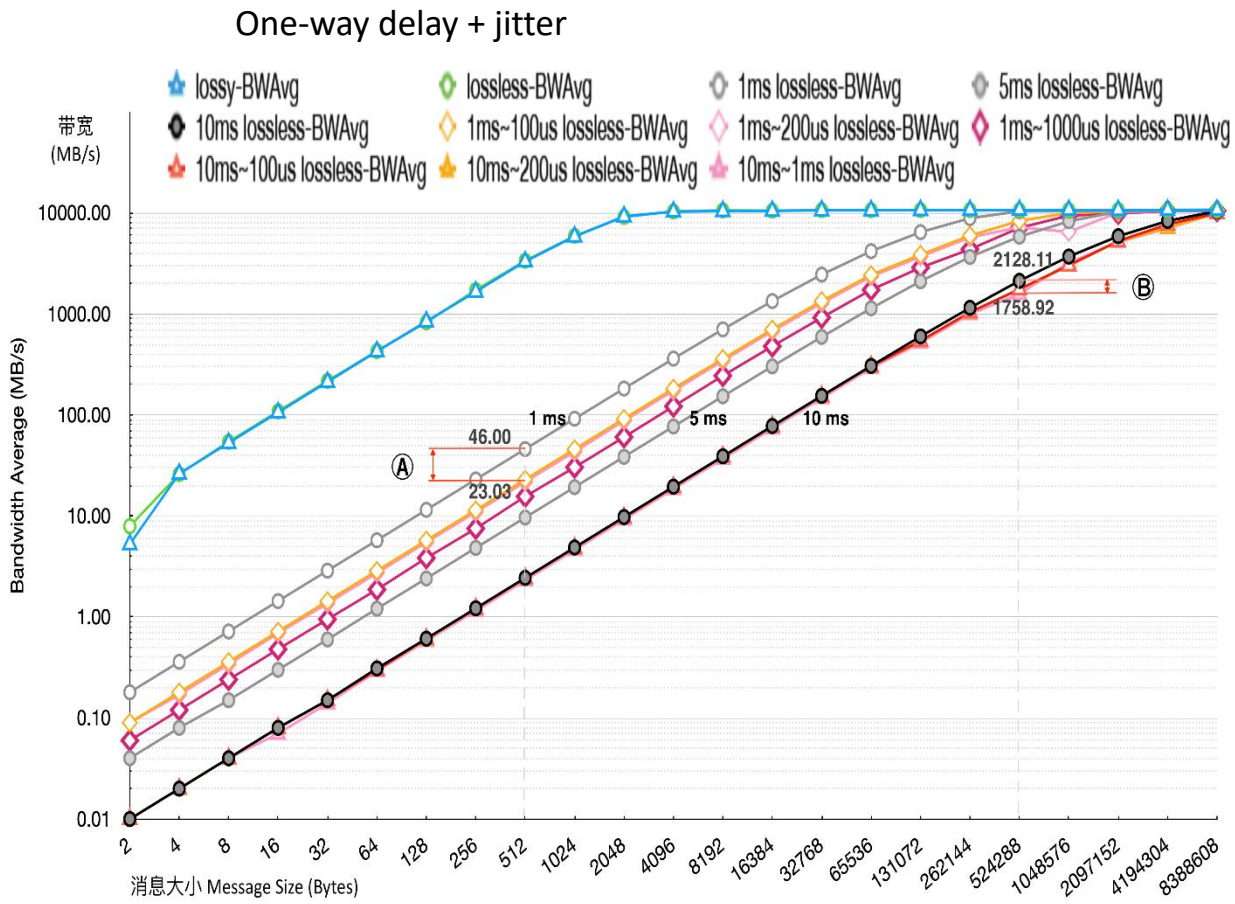
- As latency increases (1-20 ms), the RDMA message size needs to be continuously increased to achieve high-performance transmission with 100% throughput.
- It is required to provide the low latency due to the limited message size .

The impact of packet loss and latency



- It is difficult to achieve the thrughput over 70% when the packet loss rate is less than 0.001%.
- When latency and packet loss coexist and over 90% throughput of a 100G link， the packet loss rate in the data center must be less than 0.005%.
- When latency increases, it require the network to achieve ultra-low packet loss.

The impact of latency and jitter



- The simulation results using a network emulator to test 0 ms, 1 ms, and 2 ms latency, plus 1 ms with added jitter (100 µs, 200 µs, 1000 µs) are as following :
  - 1 ms + 100 µs jitter results in overall inferior performance compared to 2 ms latency with zero jitter.
  - For large-message applications (message size > 1 MB), significant performance degradation occurs when jitter exceeds hundreds of microseconds.

Results and summary

- **HPWAN Performance Metrics for Wide-Area Network over long-distance transmission:**
  High throughput in WAN (RDMA) ≈ N × message size / ρ(packet loss × latency × jitter)

Distance + Latency Impact Analysis

- Increasing message size, ， achieves >80% throughput efficiency at 2000km distances
- Message length configuration depends on:
  - Specific computing-network applications,
  - Device buffer capacity
  - Cache threshold settings
- Message size is limited due to:
  Hardware memory limitations
  Threshold boundary effects

Latency + Packet Loss Impact Analysis

- Latency makes packet loss requirements exponentially stricter to achieving > 80% throughput requires:

- intra-DC (Packet Loss):
  - Loss <0.005%
- Inter-DC (Latency + Packet Loss):
  - ultral-low (<0.001%) or zero packet loss

Latency + Jitter Impact Analysis

- Jitter induces more severe throughput degradation than latency;

- To achieve 80% throughput efficiency:
- Minimum message size: >512KB
- Jitter is less than hundreds of microseconds

- Data-intensive transmission requires high-throughput with ultra-low packet loss, low latency and low jitter.
- Predictable and Deterministic networks reduce the complexity of high-throughput protocols (e.g., RDMA) on algorithm design and parameter configuration