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Transport Layer Evolutions for Service-Oriented Network

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Outline

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1. Challenges by Service-Oriented Network
2. Novel Transport Layer Designs
3. Expectations

Challenge 1: High-Throughput Distributed Service

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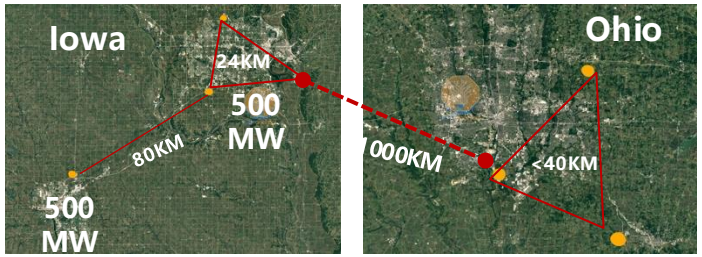
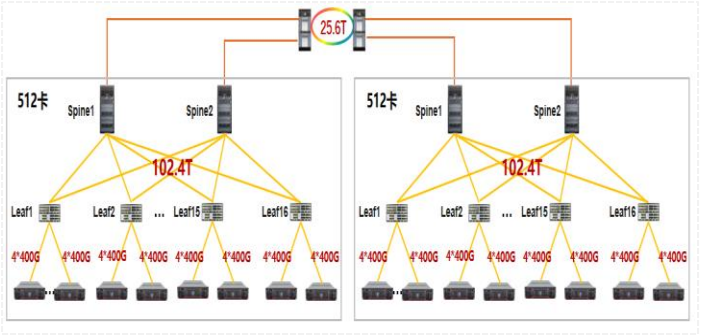
- **emerging Distributed Model as a Service (DMaaS) requires ultra-high throughput network**
  - "East-Data-West-Computing" Project
  - Global-distributed Scientific Applications





Long-Distance LLM Distributed Training

Massive Scientific Data

Distributed Computing Grid

Inter-Continent Collaboration

Challenge 2: Deterministic Service

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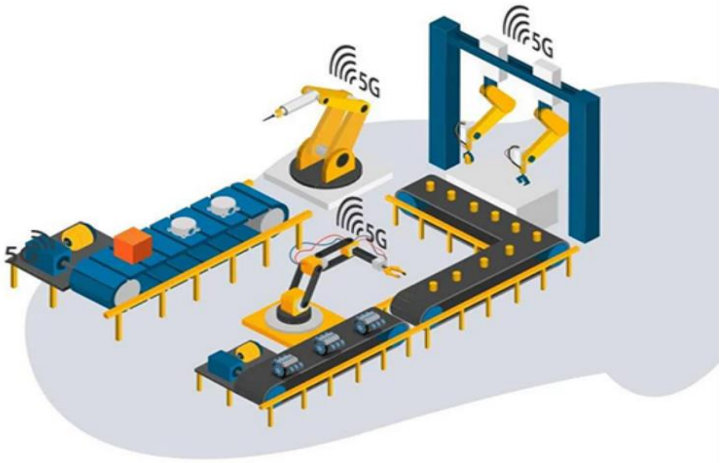
- **Deterministic Transmission for Time-Sensitive Services**
  - Synchronization time in TSN ≤ 1 μs, transmission delay jitter ≤10μs
  - Resource reservation & redundancy for high priority traffic
- **Critical Applications Requiring Millisecond Precision**



Industrial Control

The World's Main VLBI Stations

Scientific computing (multi-source synchronized data merging)

Challenge 3: Seamless Service Migration

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- **Especially in high-speed mobile scenarios**
- **Key requirements**:
  - Reliable transmission over unstable wireless networks
  - Dynamic connection switching during high-speed movement
  - connection recovery time < 100ms

Satellite Network

Vehicle Network

Challenge 4: Robust Service in Volatile Scenarios

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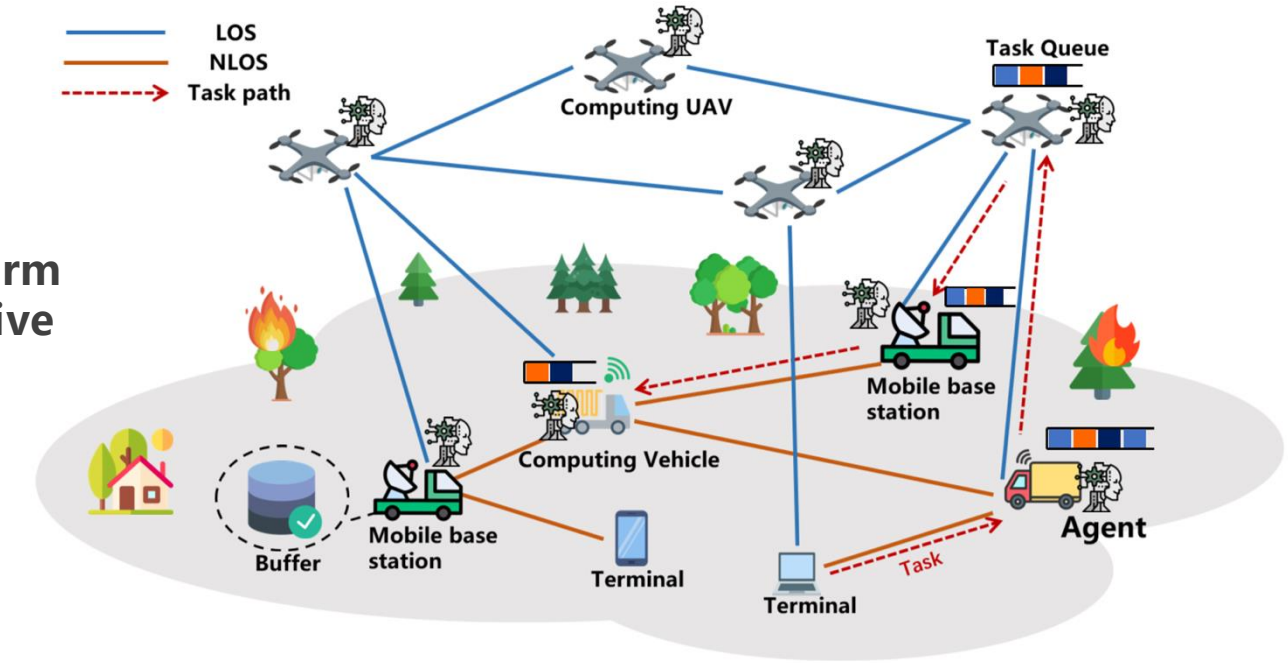
- **Weak-Link/High-Mobility Scenarios**:
  - Significant fluctuating bandwidth
  - Frequent node/link failures

- **Current Protocol Limitations**:
  - TCP/UDP cannot balance reliability/throughput
  - RDMA unsuitable for cross-DC high-speed lossless transmission
  - Inflexible endpoint-centric control

Drone swarm collaborative network



Challenge 5: Differentiated Service Guarantee

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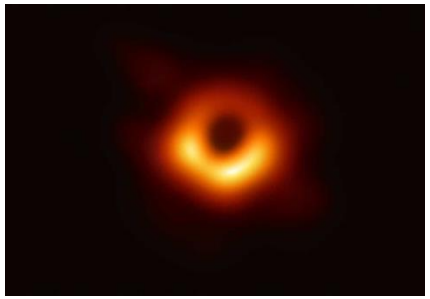
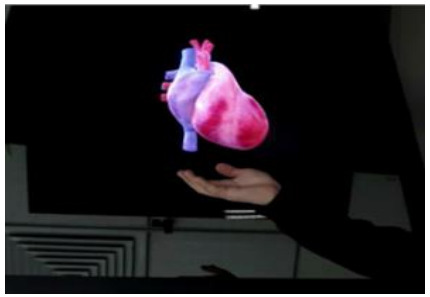
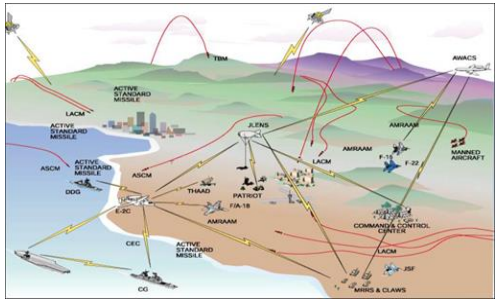
Type	Requirements	Example Applications
High Throughput	Large-scale data transfer	Astronomical observation (5PB/night ≈ 1M HD movies)
Low Latency	Millisecond response	Ultra-HD video, holographic displays, Cloud VR, cloud gaming
High Reliability	No-Fault transmission	Modern military communication networks, autonomous driving







Key Features of DMSC

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1. **In-Network Resources:** **Computing/storage resources during transmission usable for DMS**
2. **Focused Service Scenarios:** The **demand and scenarios for DMSs are mainly focused and controllable**, enabling the **refinement of common requirements**
3. **Compute-Centric Goals:** user’ s ultimate goal is **computation rather than transmission**, creating conditions for **intelligent scheduling and time multiplexing** of multiple transmission tasks.

Full-Dimensional Programmable Network Architecture

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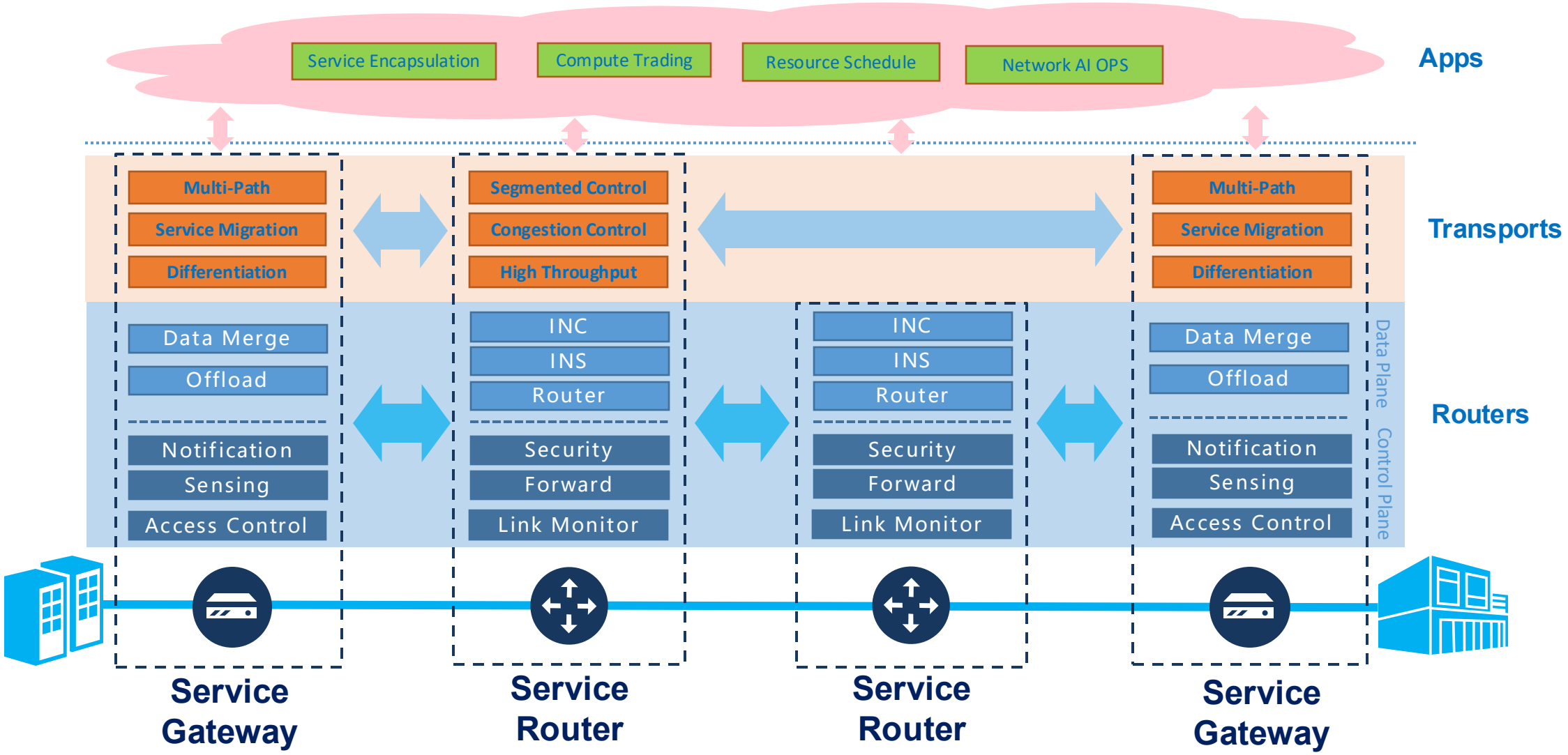
…Network can be a service



Work 1: Ultra-High Throughput Control Mechanism

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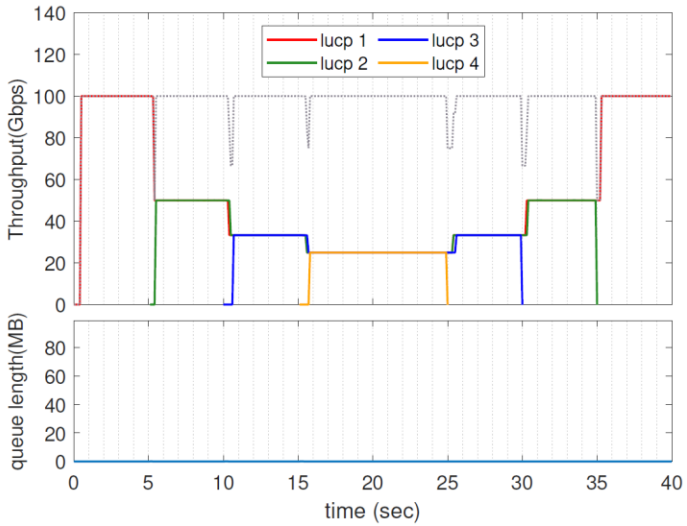
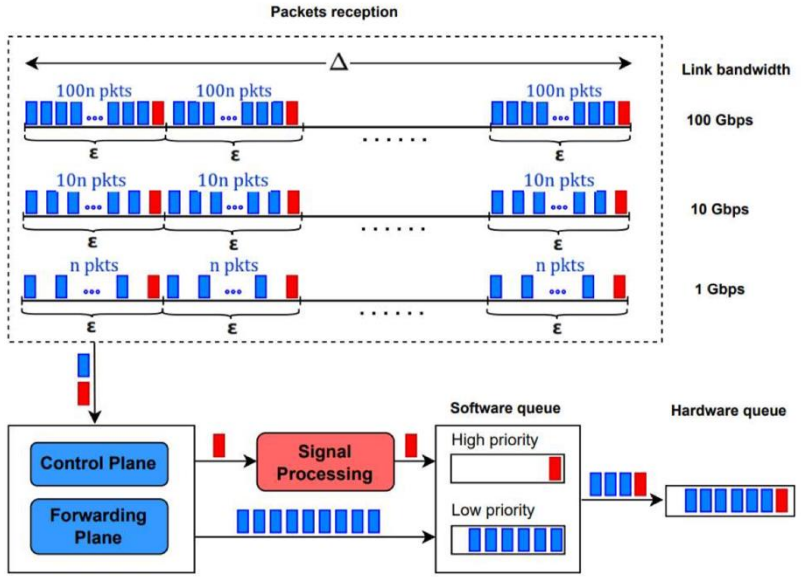
➢ Highlights

- transmission control based on a few signal packets (low processing overhead)
- In-band telemetry for precise link-state awareness
- fast, efficient and fair link bandwidth allocation with high scalability (Tbps level link)

➢ Performance

- near-zero in-network queues
- shortens flow convergence time by up to 87%





Work 2: Cross-Datacenter Congestion Control

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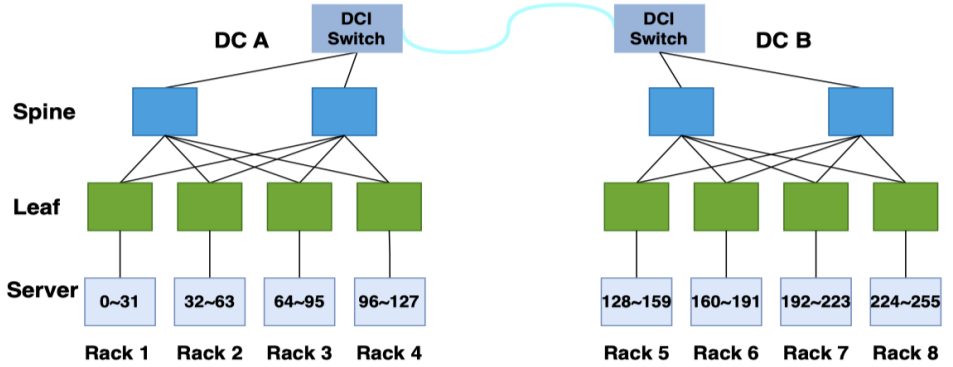
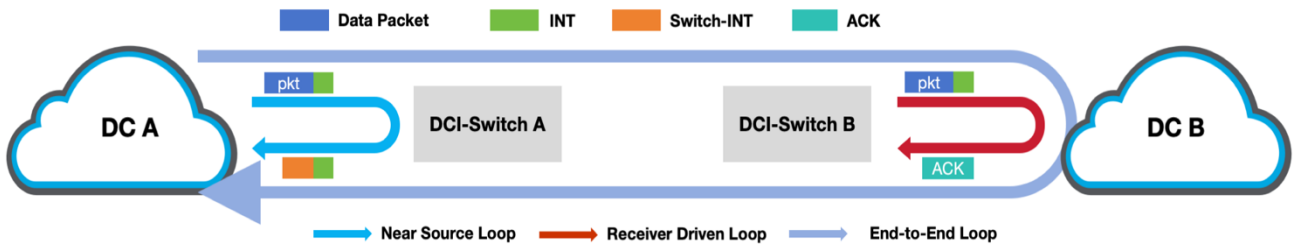
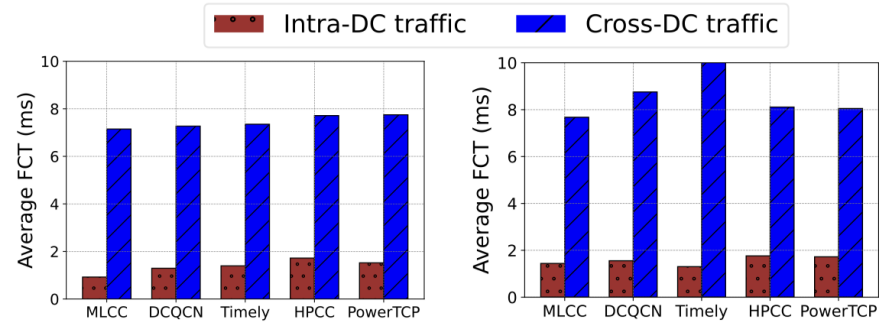
- **Highlights: fast control loop**
  - RDMA-based protocol in Cross-DCs
  - fine-grained network state awareness
  - accurate rate adaptation
  - reduce queue length in the transmission path
- **Performance**
  - reduce the average FCT of intra-datacenter and cross-datacenter traffic by up to 46% and 27%, respectively



cross-datacenter network system





(a) Avg. FCT of Websearch traffic (b) Avg. FCT of Hadoop traffic

Work3: Multi-Path Schedule and Aggregation

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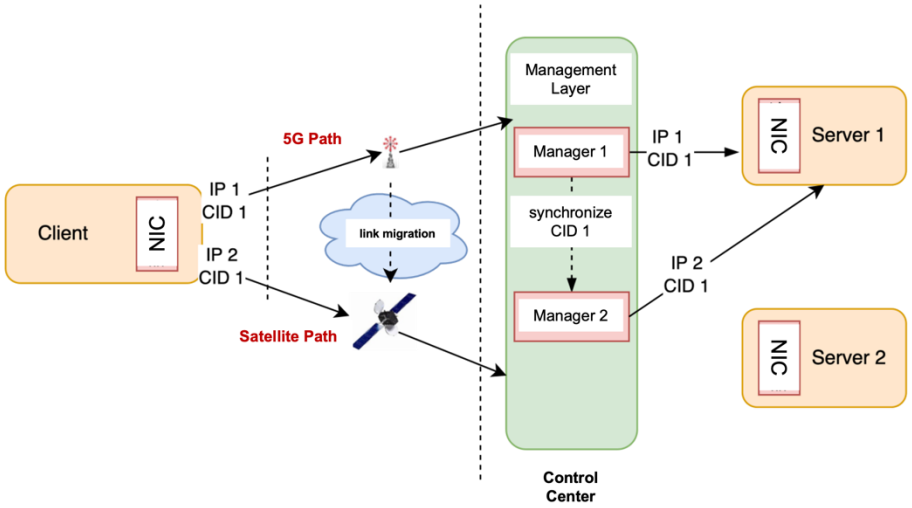
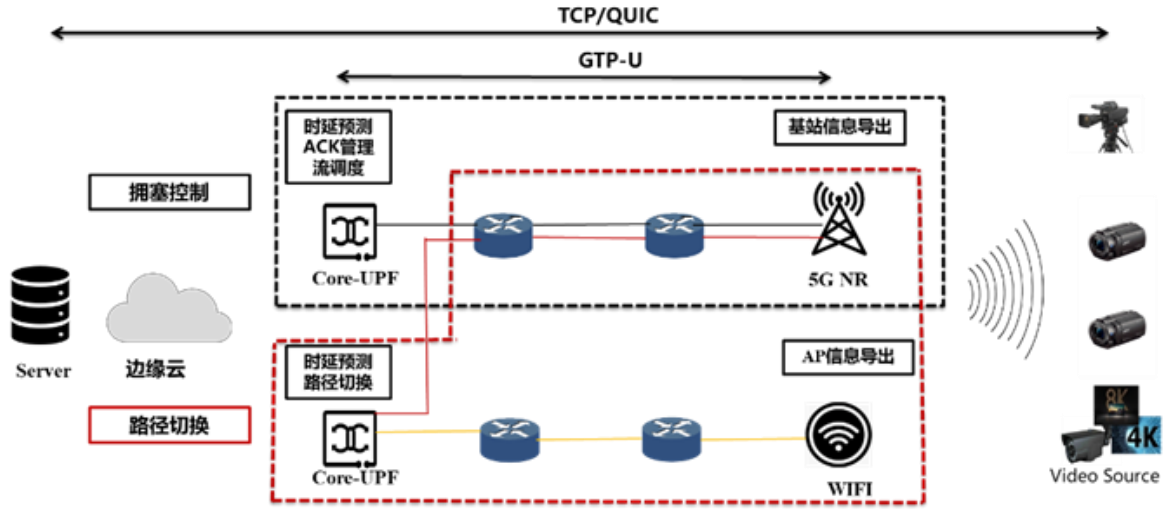
- **Highlights**
  - Priority-based dynamic connection adjustment
  - Intelligent network interface selection
  - Fast connection recovery
  - Fine-grained scheduling
- **Performance**
  - Low-latency scenarios: Stable latency regardless of packet loss
  - Bandwidth-sensitive scenarios: 10× throughput improvement



Path Switching



Path Aggregation

Work4: 5G-RAN Assisted Low-Latency Transmission

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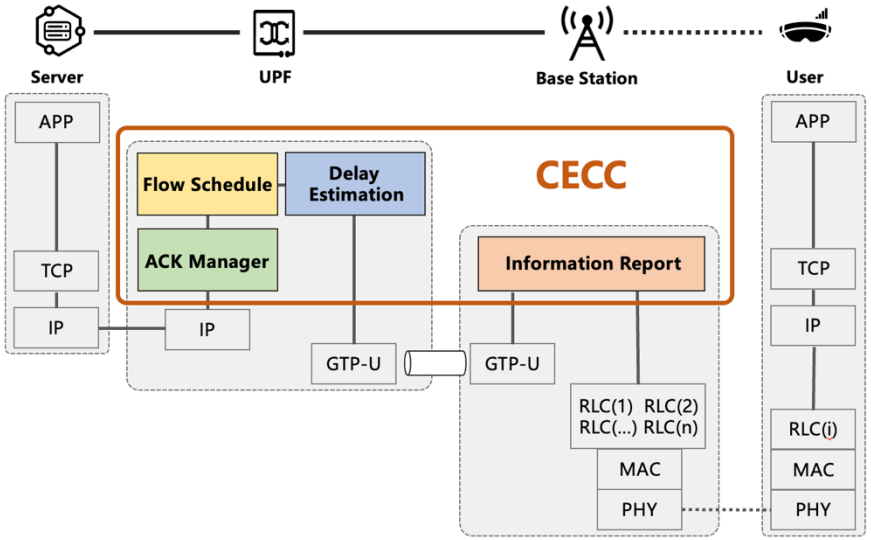
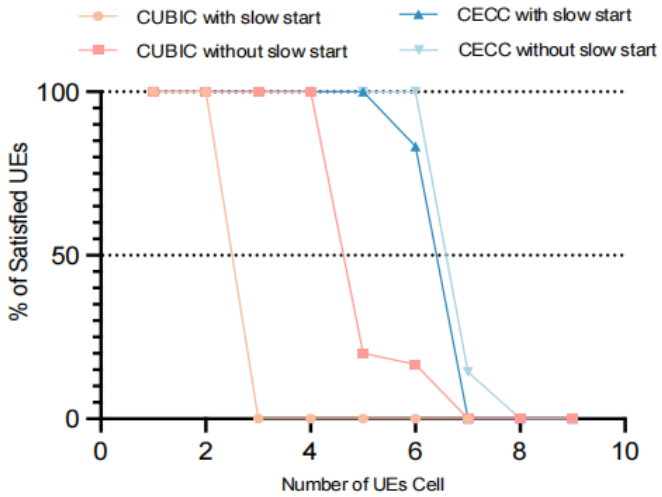
- **Highlights**
  - Base station cross-layer info acquisition (MCS, TB size, RLC buffer,...)
  - GTP-U tunnel signal transmission
  - adaptive flow control in core (UPF)
- **Performance**
  - Sub-10ms latency for concurrent users
  - Latency-Satisfied users increased from 4 UEs to 9 UEs





Work5: Differentiated Traffic Management

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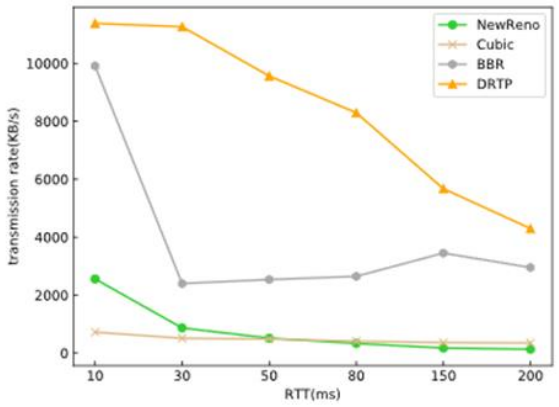
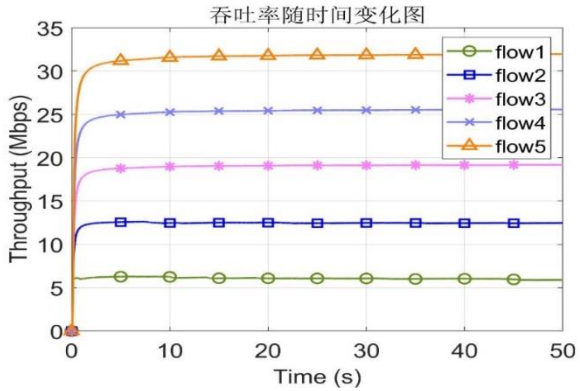
- **Highlights**
  - **Differentiated-Reliability Transport Protocol (DR-TP):** based on different reliability requirements, design fast-retransmission mechanism and congestion control algorithm
  - **Differentiated-Service Active Queue Management (DS-AQM):** manage different queues according specific flow type and performance requirements

- **Performance**

DR-TP: Reliability-guaranteed throughput boost (4× faster than BBR at 2% packet loss)



DS-AQM: Bandwidth/latency/reliability differentiation guarantee



Throughput in different weight

Hardware Deployment

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- **Functions**
  - Compute-task publishing/deployment
  - Resource metering/advertisement
  - Service metering/management

Service Gateway

- **Key Technologies**
  - Full-dimensional proprietary protocol stack
  - Task-aware load prediction (accuracy >90%)
  - Differentiated transport protocols

5G Service Base Station

Agent-based Transmission

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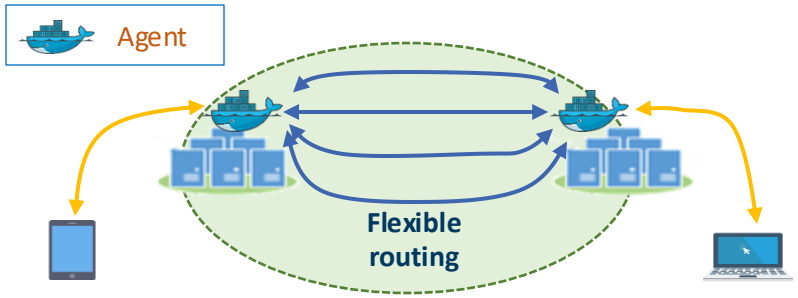
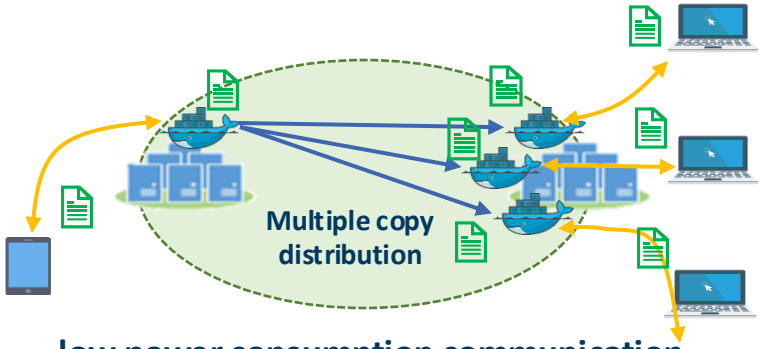
- based on the advanced in-network connection and communication between agents, making up for the deficient terminal capabilities and meet the requirements



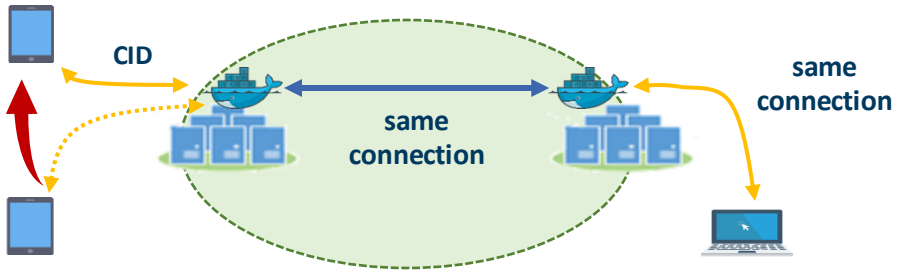
real-time communication

segmented transmission control, multiple backbone links, elastic routing



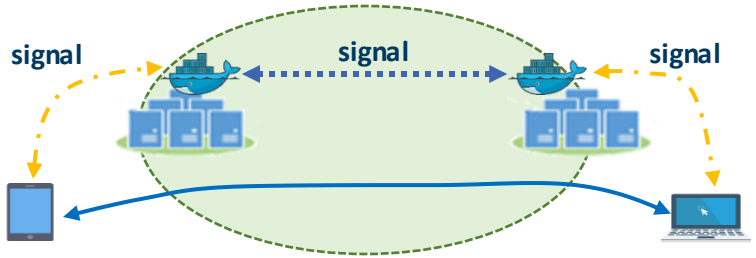
low power consumption communication

low-power transmission protocol between terminal and agent



mobility

transparent access network change to the communication peer



end-to-end

direct real-time transmission under precise signal control

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Thanks!

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