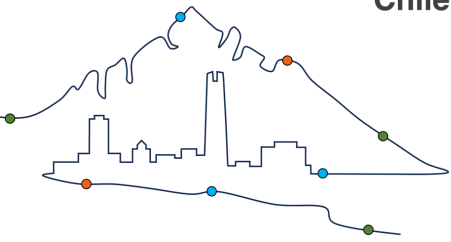


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2024

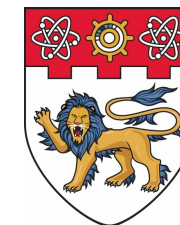
Demystifying the QoS and QoE of Edge-hosted Video Streaming Applications in the Wild with SNESet

Yanan Li^{1, 2}, Guangqing Deng², Changming Bai², Jingyu Yang², Gang Wang², Hao Zhang²,
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³ Nanyang Technological University



**NANYANG
TECHNOLOGICAL
UNIVERSITY**
SINGAPORE

Background

- Video streaming applications (VSAs) are gaining momentum .



YouTube

On-demand
video



Video
conferencing

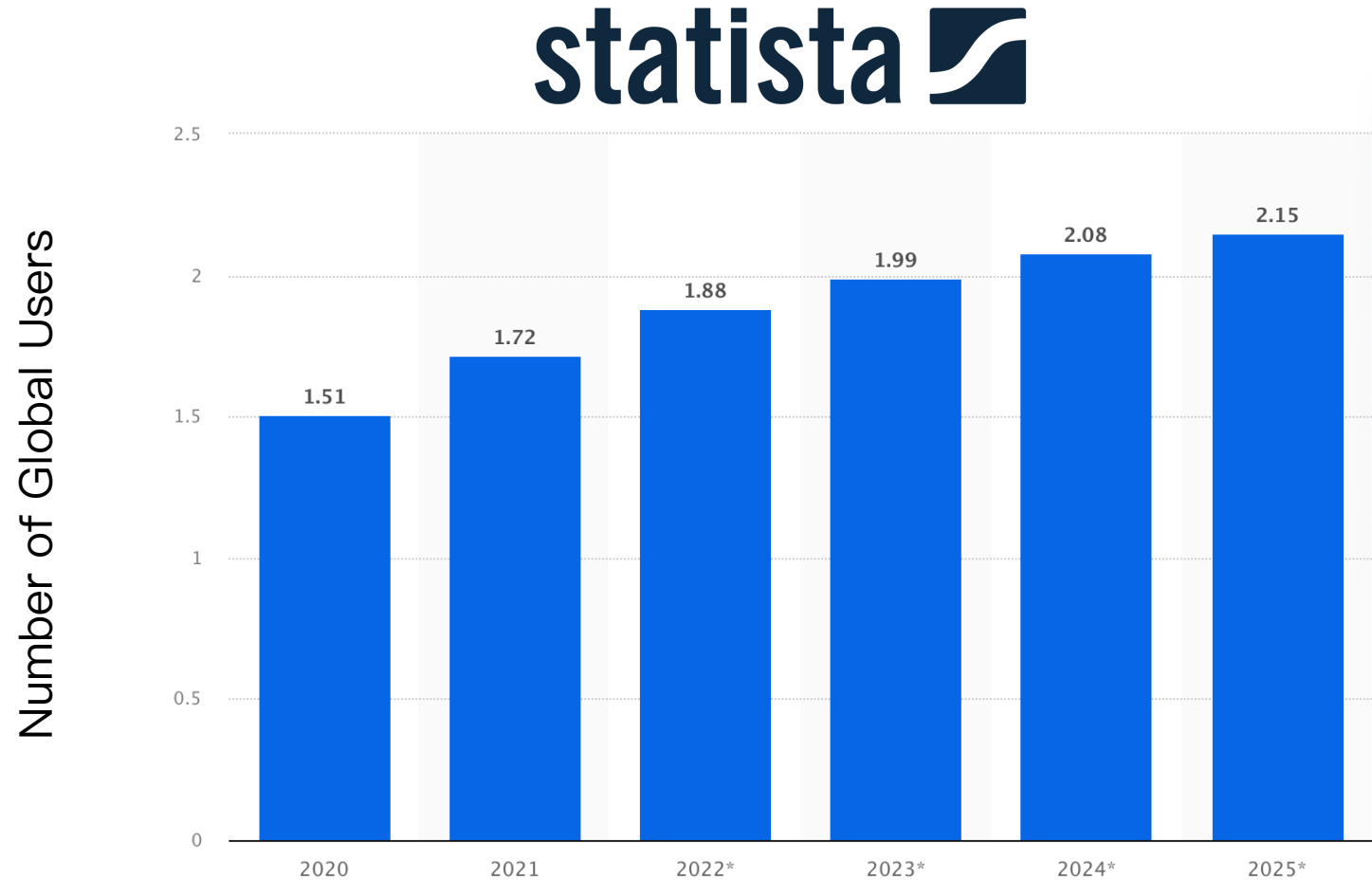


Live
streaming



Cloud
gaming

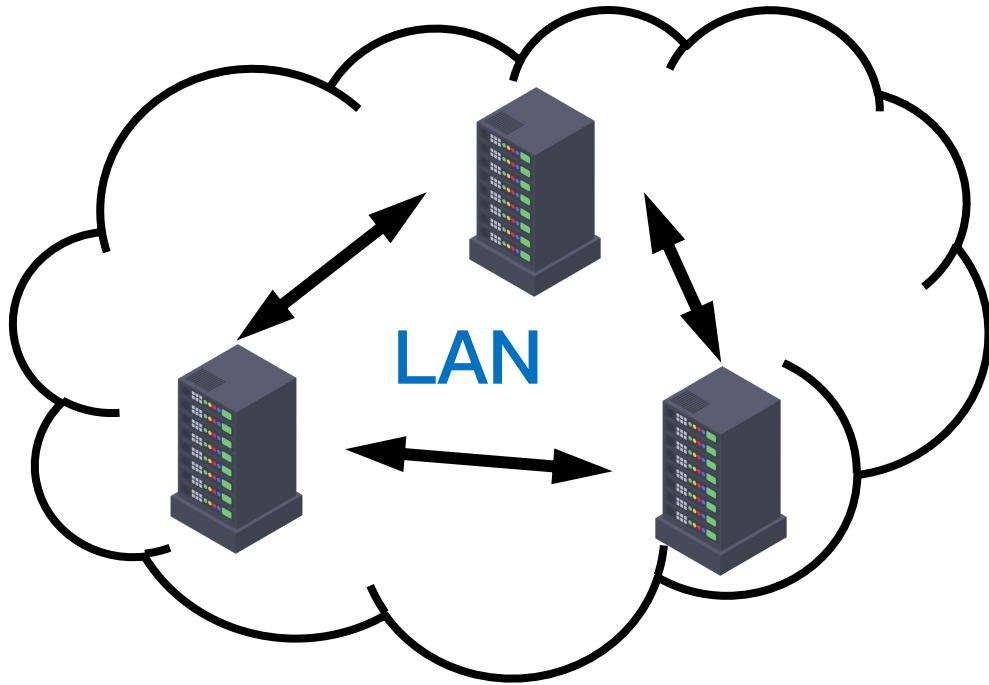
Background



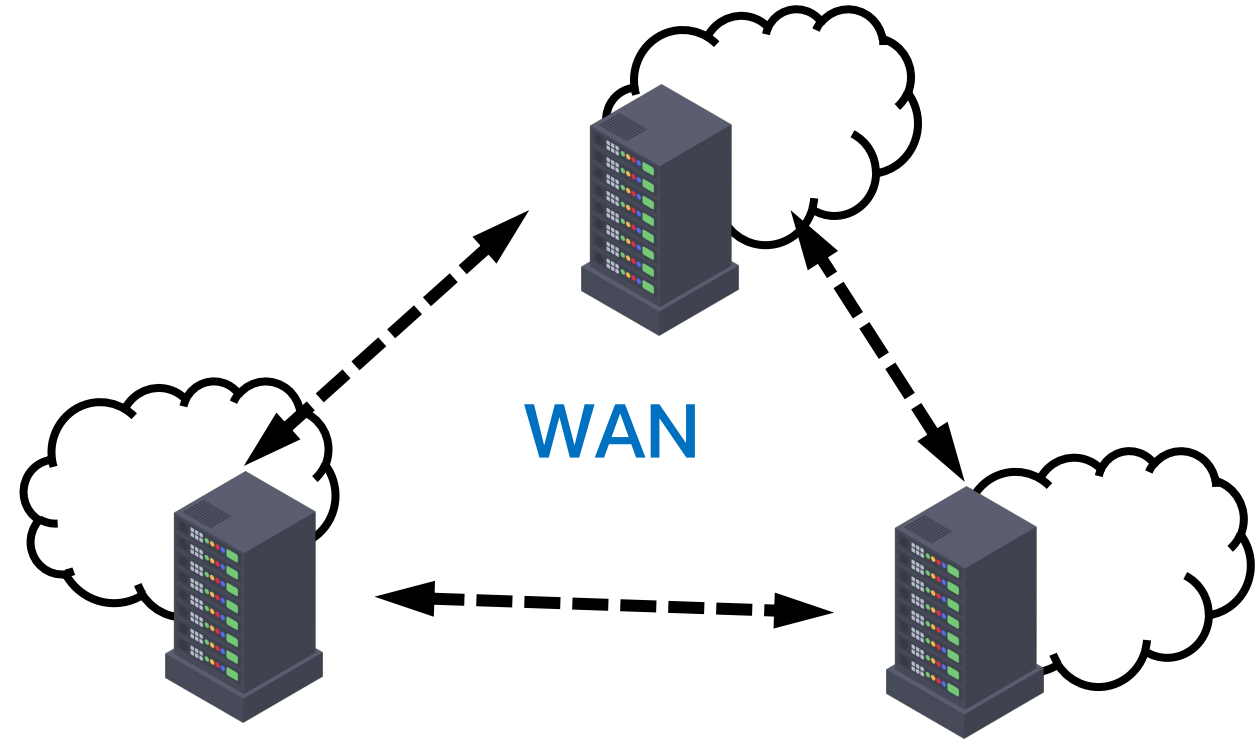
2 billion users worldwide

<https://www.statista.com/outlook/dmo/digital-media/video-on-demand/video-streaming-svod/worldwide>

Background



(a) Traditional centralized cloud



(b) Geo-distributed edge platform



What's Alibaba ENS?

- More geo-distributed micro-datacenters
 - Built atop Alibaba CDN
 - Cooperative third-party IDCs and network operators
 - Contain 2800+ edge sites in global
- Provide comprehensive services
 - FaaS, PaaS, IaaS, and heterogeneous computing (e.g., ARM SoC, FPGA)
 - 100 million peak query per seconds (QPS)

The Older Story – QoS

- QoS refers to the service quality of each component within end-to-end video delivery system.
 - Loss rate
 - Delay

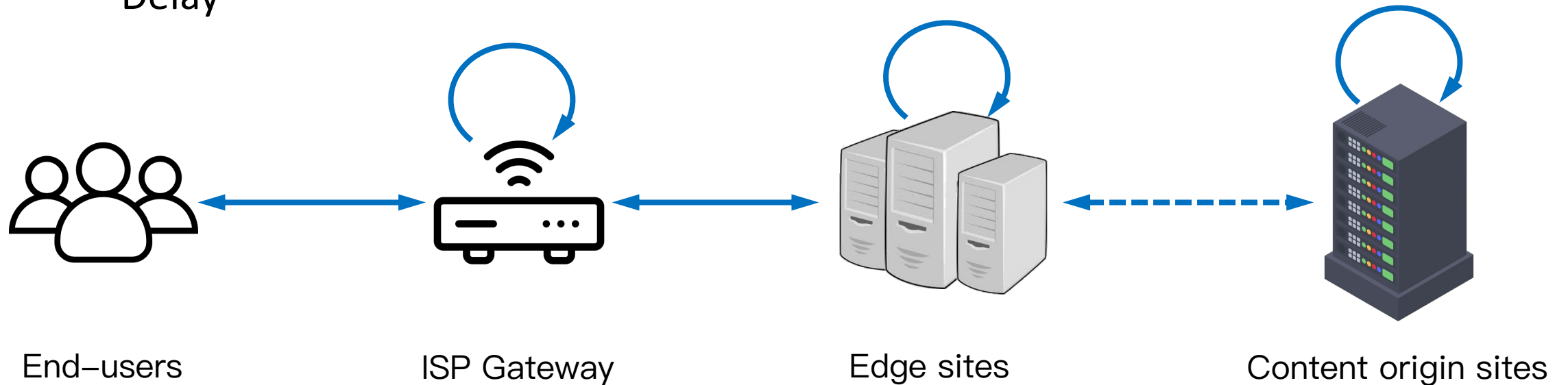


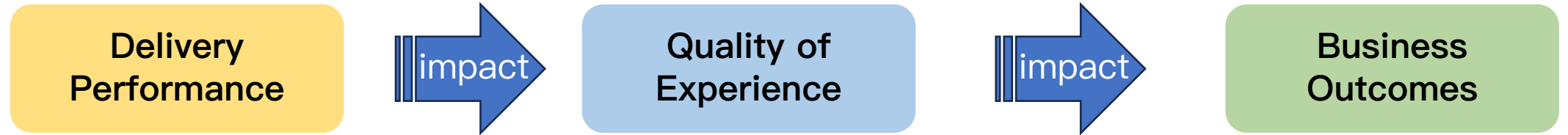
Fig 1. A example of end-to-end video delivery path.

The Newer Story – QoE

- ITU first defines QoE with Mean Opinion Score (MOS).
 - A **subjective** metric ranging from 1 to 5.
 - Subjective metrics are **expensive/complicated** to collect and are **unreliable**.
- Similar to prior research, we primarily focus on **objective** QoE such as stall/rebuffer ratio and startup delay.^[1]

[1] Xiaoqi Yin, Abhishek Jindal, Vyas Sekar, and Bruno Sinopoli. 2015. A control-theoretic approach for dynamic adaptive video streaming over HTTP. In Proceedings of the ACM SIGCOMM Conference. 325–338.

How QoS and QoE matter?



💡 For example, a 100ms decrease in page load time can lead to an 8% better conversion rate for retail sites (around 4 billion dollars) ^[2].

[2] Deloitte Digital. 2020. Milliseconds make millions: A study on how improvements in mobile site speed positively affect a brand's bottom line. <https://bit.ly/3rpm8WP>.

Limitations of Existing Datasets

Table 1. Comparison with existing publicly available cloud/edge datasets.

Dataset	QoS (server-side)	QoE	Platform	Year	Duration	# of Sites	# of Network Protocol Stacks
Alibaba Dataset [38]	✓	✗	Alibaba ECS	2018	8 days	1	1
Google Dataset [100]	✓	✗	Google Borg	2019	1 month	1	1
Azure Dataset [27]	✓	✗	Azure Cloud	2019	30 days	1	1
Edge Dataset [112]	✓	✗	Alibaba ENS	2020	3 months	139	2
LiSSi lab Dataset [7]	✗	✓	Testbed	2015	1 week	1	1
Puffer [114]	✗	✓	Testbed*	Since Jan 2019	Keep updating	1	2
Huawei Dataset [102]	✓	✓	Testbed	2018	1 month	1	3
SNESet (Ours)	✓	✓	NEP	2022	4 months	789	4

* While we classify the Puffer [114] as a testbed, it falls somewhere between a traditional testbed and a real-world commercial system.

(1) Comprehensive coverage

(2) Collected from large-scale platform in the wild

SNESet: The SOTA of QoS and QoE Datasets

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Edge Dataset [112]	✓	✗	Alibaba ENS	2020	3 months	139	2
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SNESet, an active measurement of 8 VSAs spanning four months in 2022, covering end-users from 798 edge sites, 30 cities, and 3 ISPs in China.

Comprehensive Coverage of SNESet

Metrics	Taxonomy	Type	Net Stack	Description	Example
date_sequence	Context	BIGINT	-	The day of the month, which ranges from [1, 31].	21
hour_sequence	Context	BIGINT	-	The hour of the day, which ranges from [0, 23].	5
domain_name	Context	STRING	-	The domain name identifier, which represents different applications.	domain_18
city	Context	STRING	-	The city identifier.	city_14
isp	Context	STRING	-	The ISP identifier.	isp_10
node_name	Context	STRING	-	The edge site identifier.	node_12
avg_fbt_time	QoS (server-side)*	BIGINT	5	The average first-byte time represents the time from the edge site receiving the request to sending the first response packet (unit ms).	12
inner_net_droprate	QoS (server-side)	DOUBLE	3	Edge site internal network packet loss rate (%)	0.001
inner_net_rtt	QoS (server-side)	BIGINT	3	Edge site internal network round trip time (ms)	2
cpu_util	QoS (server-side)	DOUBLE	1	Edge site average CPU utilization	0.56
mem_util	QoS (server-side)	DOUBLE	1	Edge site average memory utilization	0.62
io_await_avg	QoS (server-side)	BIGINT	1	Edge site average I/O waiting time	31
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ng_traf_level	QoS (server-side)	DOUBLE	1	Edge site normalized bandwidth level in range [0, 1)	0.88
synack1_ratio	QoS (client-side)	DOUBLE	4	One-time success rate of establishing TCP connections.	0.86
tcp_conntime	QoS (client-side)*	BIGINT	4	The time from when the server receives a SYN packet to when it receives an ACK from the client (ms).	33
icmp_lossrate	QoS (client-side)	DOUBLE	3	The ICMP (Layer 3) packet loss rate	0.05
icmp_rtt	QoS (client-side)	DOUBLE	3	The ICMP (Layer 3) round trip time (ms)	21
499_5xx_ratio	QoS (client-side)	DOUBLE	5	The ratio of 499 and 5xx issued by Tengine	0.01
reset_ratio	QoS (client-side)	DOUBLE	5	Percentage of reset requests	0.22
buffer_rate	QoE	DOUBLE	5	The percentage of the video that experiences frozen or stalling events during the playback period.	0.04

Context Info

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e/53

* Moreover, the startup delay QoE metric can be approximated by $4 * \text{tcp_conntime} + \text{avg_fbt_time}$.

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Link & Physical Layer
(Layer 1 & 2)

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1/53

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Network Layer
(Layer 3)

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4/53

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Transport Layer
(Layer 4)

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Comprehensive Coverage of SNESet

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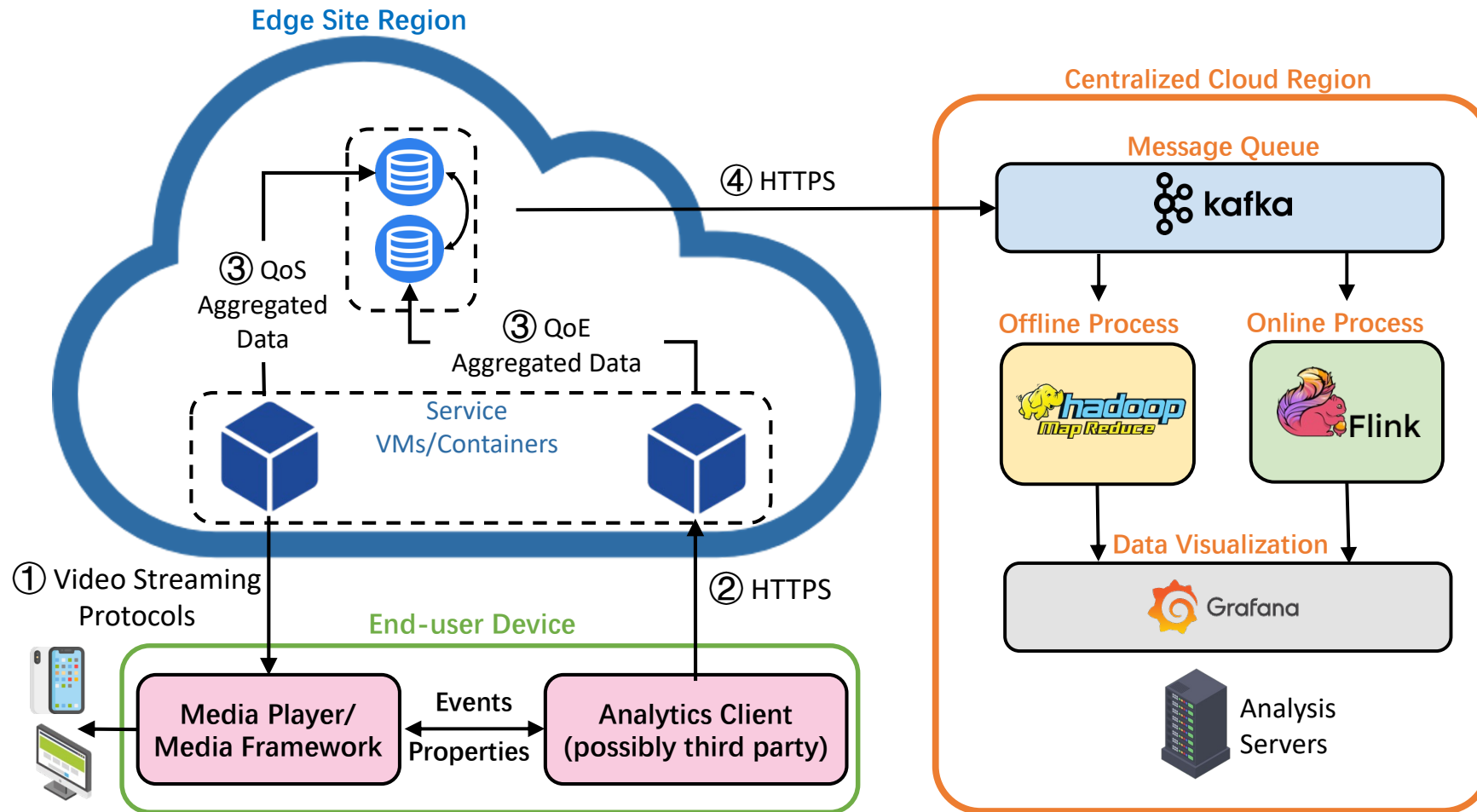
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Application Layer
(Layer 5)

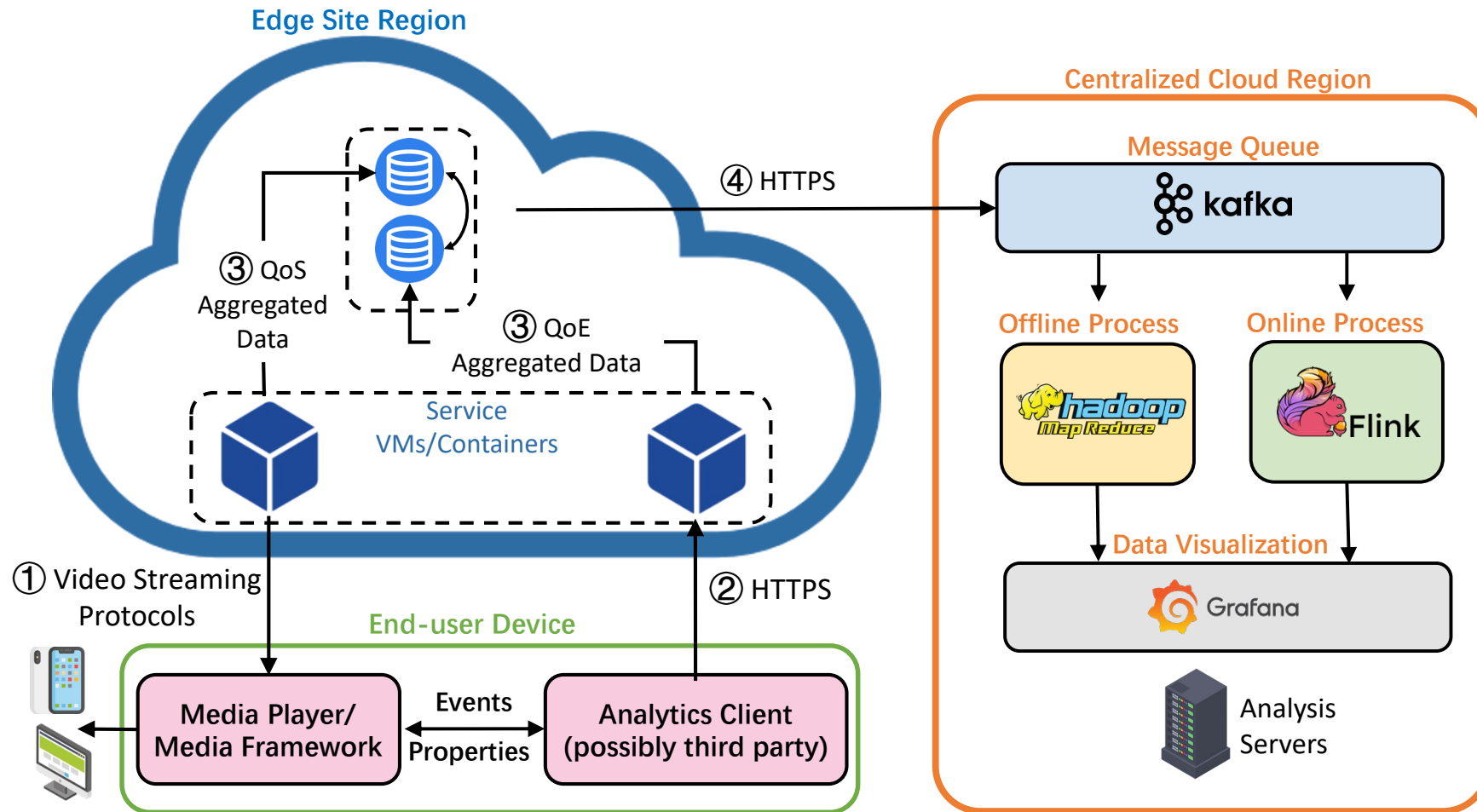
5*/23

2*/53

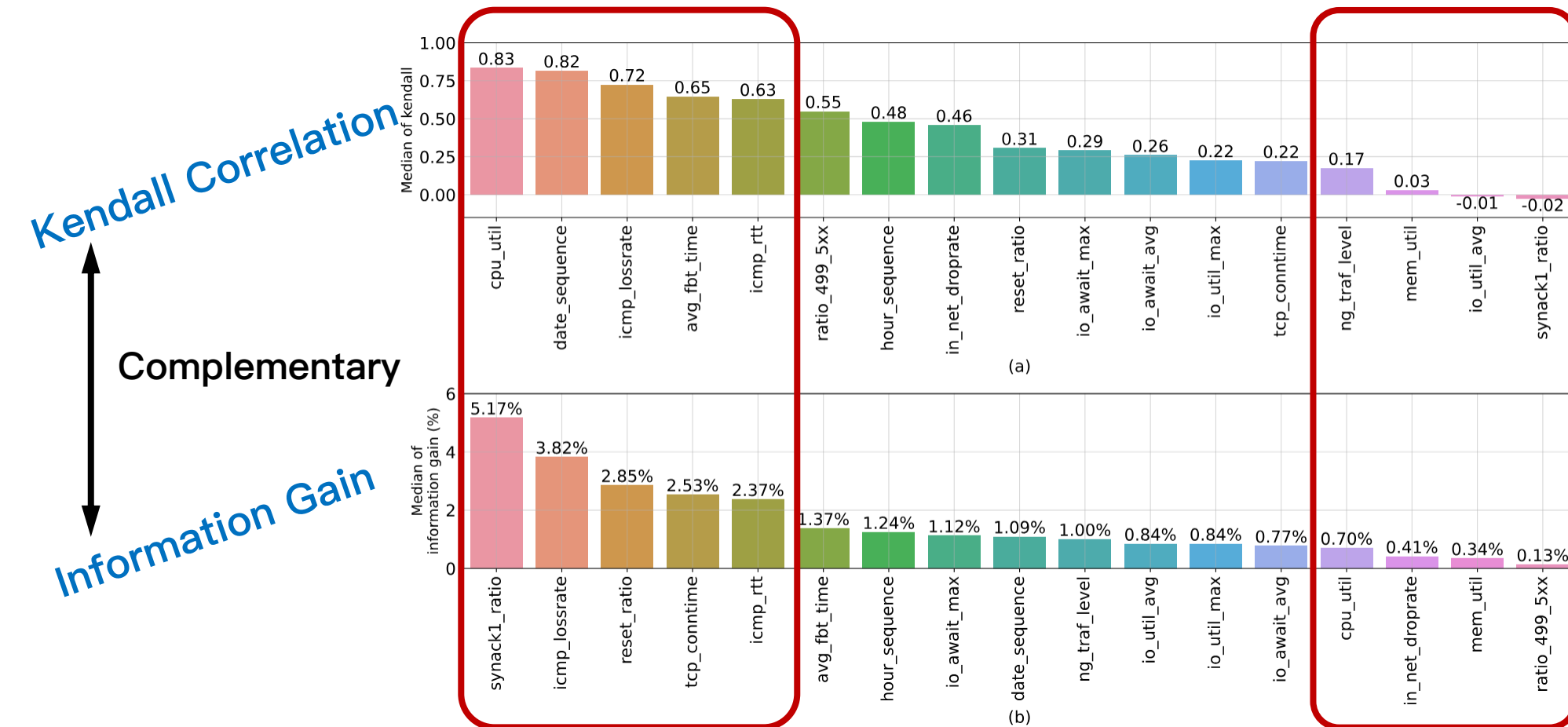
Data Collection System



Data Collection System



Qualitative Analytics



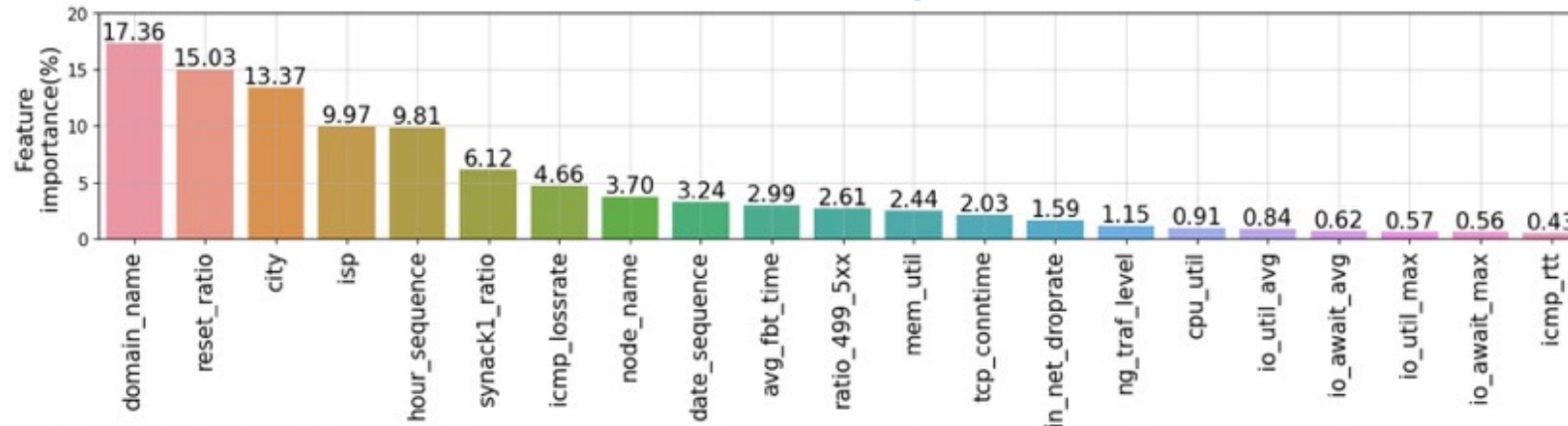
Implications

- (1) End-to-end performance is critical.
- (2) Co-locate with memory or I/O-intensive services.

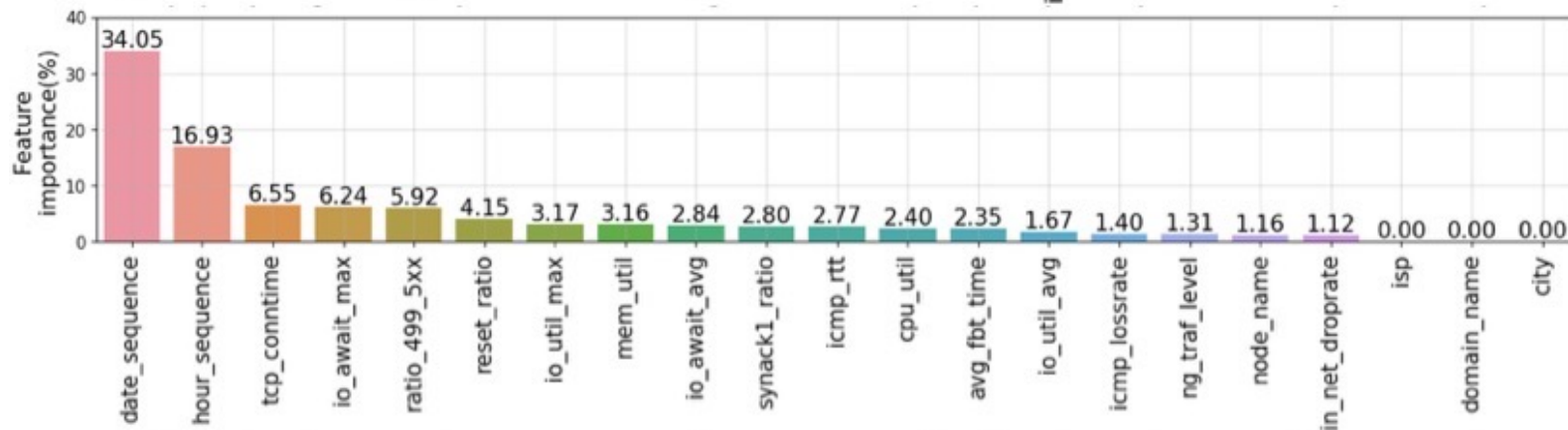
Quantitative Analytics

CatBoost feature importance score

Domain-agnostic



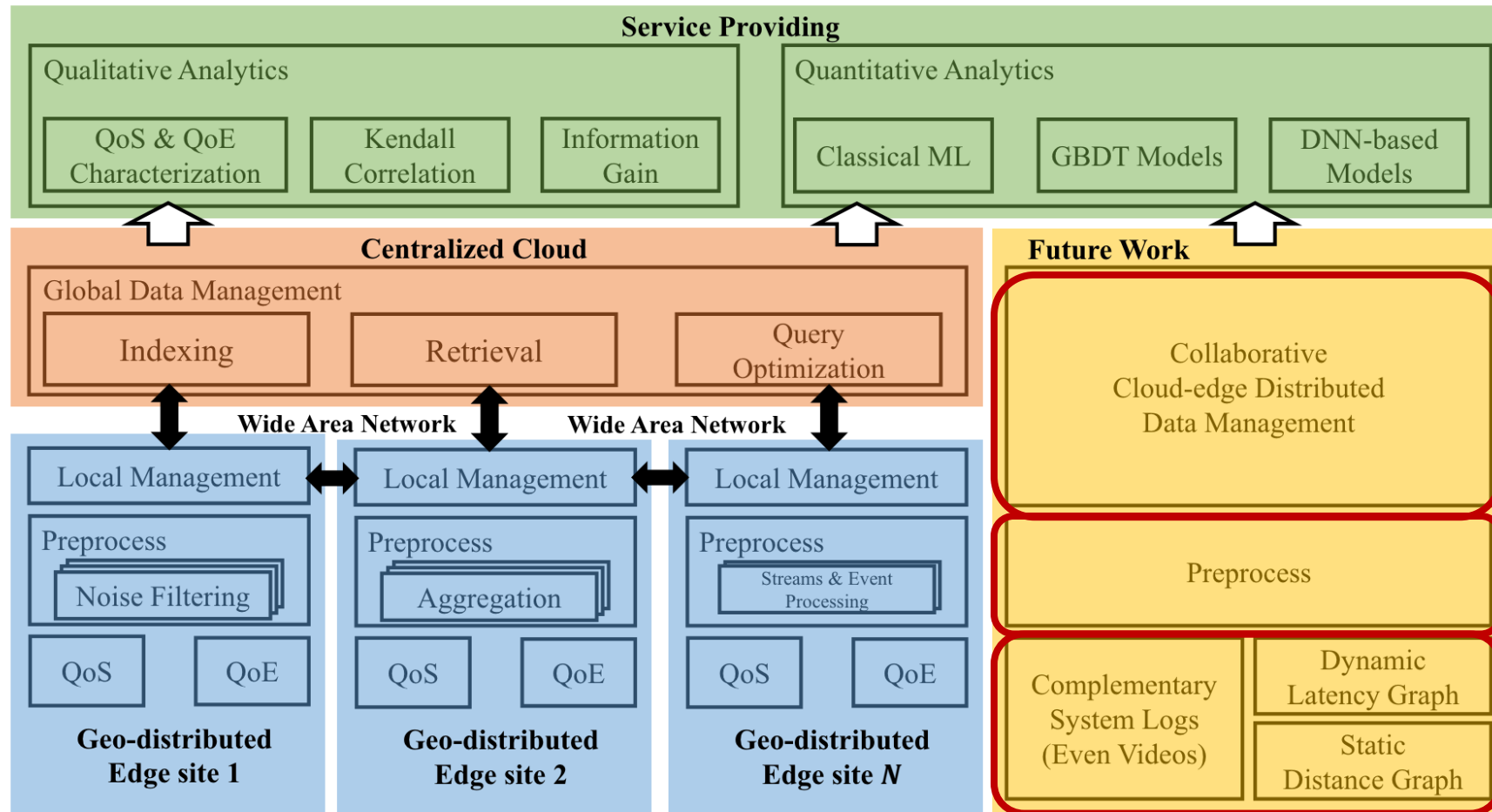
Domain-specific



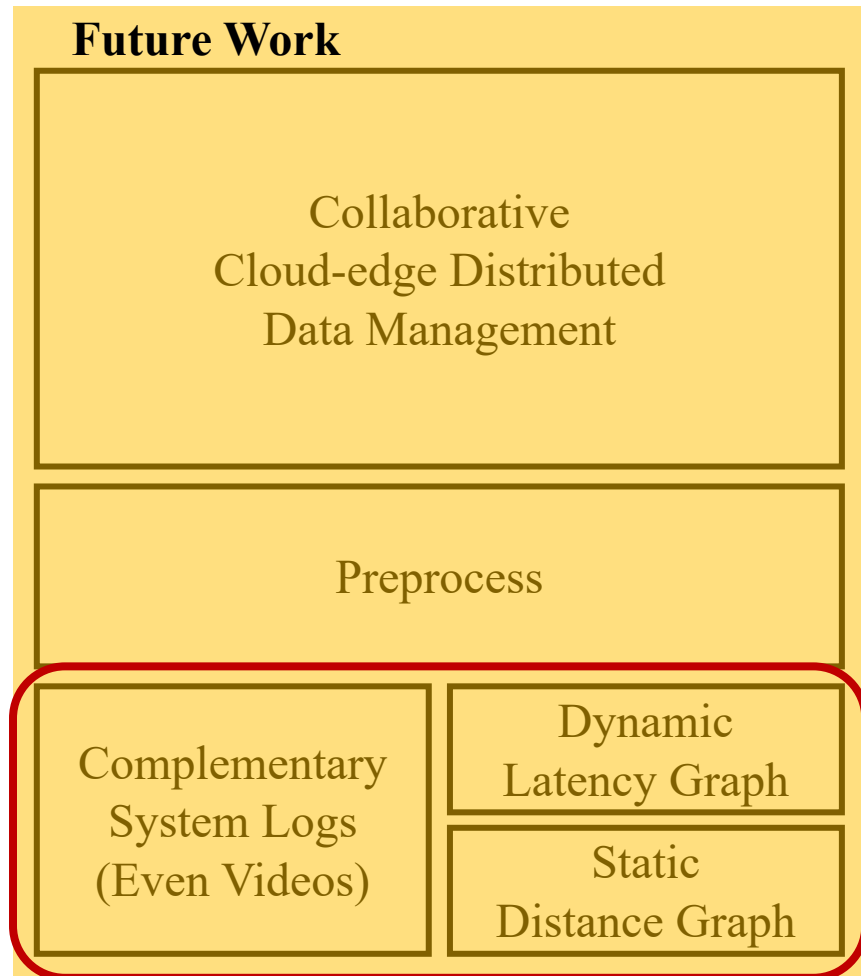
Implications:

One-size-fits-all QoS-based QoE prediction model aren't applicable.

Potential Data-centric Problems

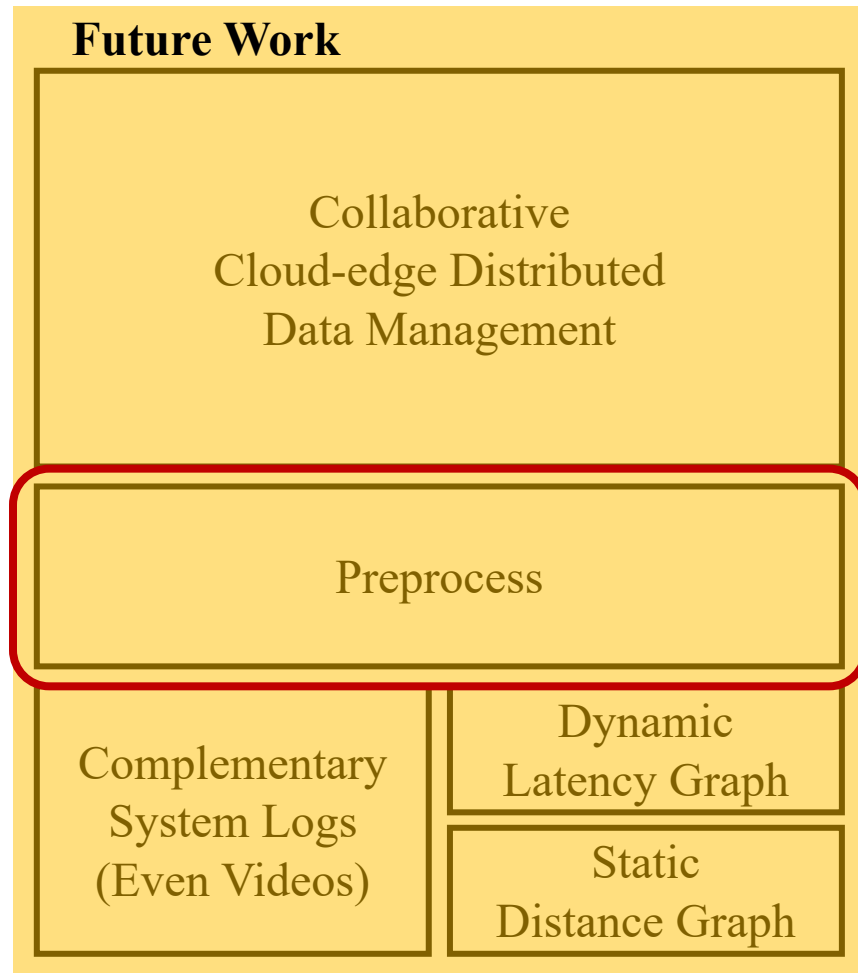


Data Collection Challenges



- **Objectives:** Accurately reflects end users' QoE while minimizing the costs.
 - Lightweight implementations;
 - Low runtime costs;
 - Efficient integration with both the internal and external datasets.

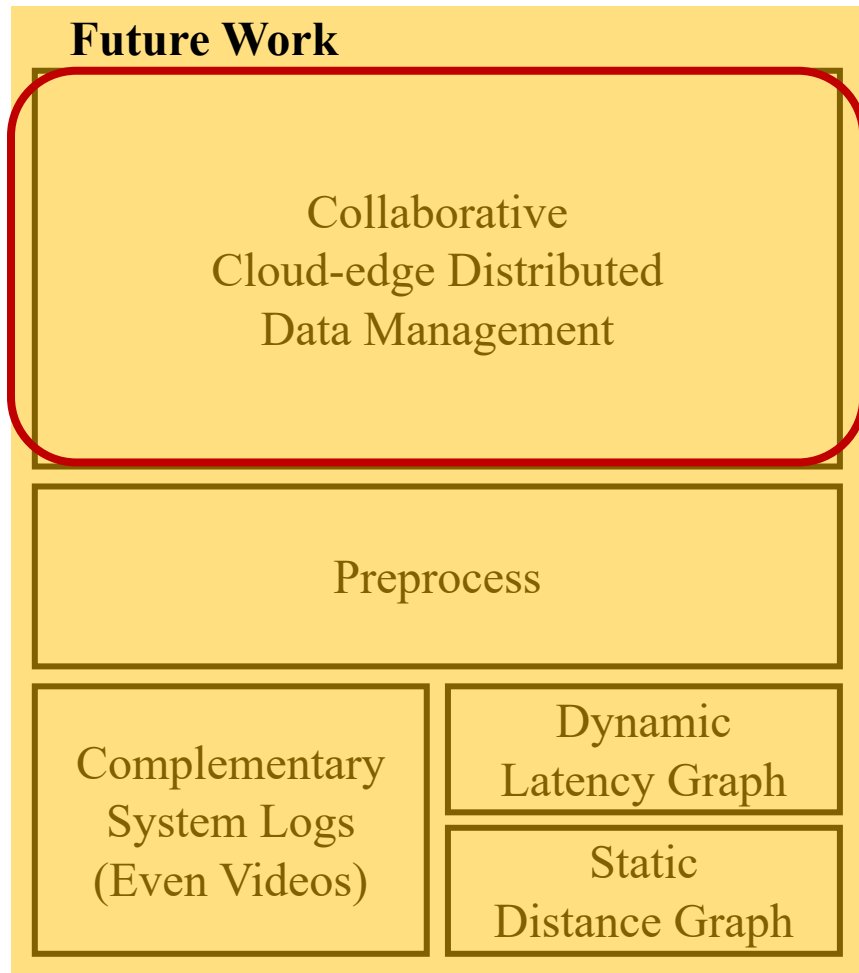
Data Preparation Challenges



The daily data volumes of each edge sites is about terabytes (TB, 10^{12}).

- Filtering redundant information for resource-constrained edge sites
- Data augmentation for class imbalance issue

Data Management Challenges



- Limitations of the existing centralized data management:
 - Network bandwidth overhead
 - Transmission time consumption.
- Key considerations:
 - Diverse data type: structured QoS, semi-structured QoE/system logs, graph data, and even videos.
 - Large-scale geo-distributed sites connected through WAN.
 - Automated materialized views

Conclusions

- We have collected **SNESet**, which contains both QoS and QoE metrics for eight VSAs on a large-scale edge platform using active measurements.
- **Qualitatively** and **quantitatively** analyze the impact of different QoS metrics on QoE in both **domain-agnostic** and **domain-specific** scenarios.
- Potential data-centric problems.

Thanks for listening!

Paper: Demystifying the QoS and QoE of Edge-hosted Video Streaming Applications in the Wild with SNESet

Dataset & Code: <https://github.com/YananLi18/SNESet>

Acknowledgments:

Special thanks to Alibaba Group

Mail to: YaNanLi@bupt.edu.cn

