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Measurements and Analysis of MQTT Response Times in Cloud and Edge with 5G and Wi-Fi 6

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***Abstract*—Cloud and edge computing play a crucial role in enabling the intelligence of Industry 4.0, while wireless technologies like 5G and Wi-Fi 6 enhance its flexibility. However, selecting the appropriate technologies is nontrivial. In this paper, we present our measurements (over 360 hours) and analysis of response times in cloud and edge computing using different network access methods. We provide recommendations for technology selection based on our findings. Our results highlight the unique advantages of 5G and Wi-Fi 6 at different percentiles, and the characteristics of cloud and edge computing in terms of workload processing and network propagation. The choice between these technologies should consider the Quality of Service (QoS) requirements and processing workloads of applications, as well as the computational resources of edge and cloud servers.**

***Index Terms*—Industry 4.0, Cloud, Edge, 5G, Wi-Fi 6, MQTT**

I. INTRODUCTION

One characteristic of Industry 4.0 is flexible customization [1]. However, traditional wired devices limit flexibility, as customization or reconfiguration demands complex cable adjustments [2]. To address this, wireless technologies like 5G and Wi-Fi 6 have been adopted to enhance industrial production flexibility [3]. Another characteristic of Industry 4.0 is intelligent production [4], which requires significant computational power for data processing and decision-making [5]. Cloud and edge computing provides the necessary computational resources to support these demands [6]. However, 5G and Wi-Fi 6 have different characteristics. Remote cloud servers and edge servers also differ in computational capacity and network conditions. Consequently, selecting between 5G and Wi-Fi 6, as well as between cloud and edge computing, can be complex. Therefore, in this paper, we present our measurements comparing the performance of cloud and edge computing across different network access methods, to provide recommendations on choosing among these technologies.

Given the time-sensitive nature of most industrial production operations [7], their most important performance metric is response time, which comprises uplink time, processing time, and downlink time. For instance, in a closed control loop involving an industrial device such as an Autonomous Mobile Robot (AMR) or a robotic arm, the device initially reports its status to the controller, incurring uplink time. Subsequently, the controller processes the device status to determine the next instruction, bringing about processing time. Finally, the controller dispatches the next instruction to the device, introducing downlink time. Therefore, in our measurements, we consider response time and its three components as performance metrics. Our key contributions include:

- Developing Message Queue Telemetry Transport (MQTT)-based applications named Processing and Networking Measurement Tools (PNMTs) to simulate the behavior of an industrial *device* and its *controller* in our measurements.
- Performing 9 long-time measurements (each lasting $39-45$ hours) to compare the performance and stability of cloud and edge computing with Ethernet, 5G, Wi-Fi 6, and multi-connectivity.
- Performing 18 short-time measurements (each lasting $41-61$ seconds) to compare the performance of cloud and edge computing with varying processing workloads.
- Analyzing the advantages and disadvantages of different technologies and providing recommendations on their selection.

The remainder of this paper is structured as follows. Section II reviews related works. Section III details our measurement methodology. Section IV analyzes the measurement results and provides recommendations for selecting among the measured technologies. Section V concludes this paper, discussing its limitations and future works.

II. RELATED WORK

Various performance metrics for cloud, fog, and edge computing, such as response time, throughput, and privacy, are discussed in [8], but this work does not include practical measurements. A performance comparison between Microsoft Azure, Amazon Web Services (AWS), and Google Cloud Platform (GCP) is presented in [9], but the evaluation relies on benchmarking tool scores rather than real-world performance metrics like response time. Palumbo et al. [10] measure response time between globally distributed cloud servers and users. However, the fixed processing workload in these measurements makes the computational capacity assessment incomplete, and the message rate of one message per minute is not consistent with industrial time-sensitive operations.

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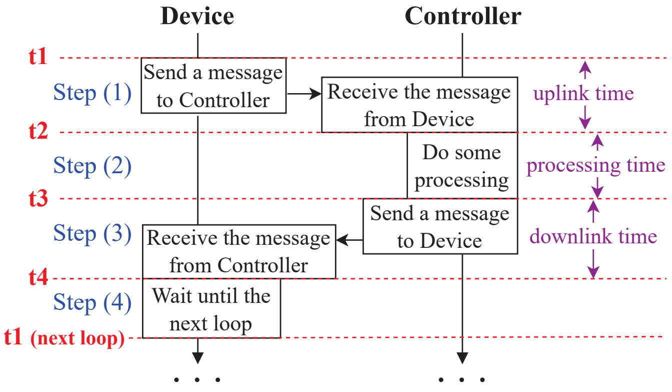

Fig. 1. Workflow of communication between the PNMT device and controller.

In terms of the measurements of network access methods, Liu and Choi [11] compare Wi-Fi 6 and legacy Wi-Fi experimentally but do not include other access methods such as 5G. Maldonado et al. [12] compare the downlink performance of Wi-Fi 6 and 5G, focusing on offered load rather than network latency. Canellas et al. [13] compare Wi-Fi 6, 5G, LiFi, and their multi-connectivity, but the measurement duration, equivalent to the time it takes a person to walk 6.7 kilometers, is too short to evaluate stability.

Existing studies focus on either cloud and edge computing or different network access methods, but none of them combines these two aspects. To the best of our knowledge, this is the first work to conduct joint evaluations of both dimensions by simulating real industrial production using MQTT, a prevalent Industrial Internet of Things (IIoT) protocol [14].

III. MEASUREMENTS METHODOLOGY

A. PNMTs Applications and Performance Metrics

In order to closely mimic real-world industrial production in our measurements, we have developed PNMTs, a pair of applications that simulate the behavior of an industrial *device* and its *controller*. The PNMTs comply with the Industry 4.0 principles of interoperability and scalability by communicating using MQTT, a vendor-neutral publish/subscribe protocol widely employed in IIoT applications [14]. Fig. 1 illustrates the workflow of the PNMTs, which can be outlined in four steps: (1) the device sends a message to the controller, mimicking the reporting of device status; (2) the controller performs a processing task, mimicking the analysis of the device status to generate the corresponding instruction; (3) the controller sends a message back to the device, mimicking the dispatching of the instruction; (4) the device waits for some time until the next loop, mimicking the message rate in real-world industrial production. The PNMTs repeat these four steps indefinitely until manually stopped by a user. The PNMTs device and controller record four critical timestamps $t1$, $t2$, $t3$, and $t4$ as shown in Fig. 1, which are used to calculate the following performance metrics in our measurements:

- *Uplink time*: Duration from the device sending a message to the controller receiving it, calculated as $t2 - t1$.
- *Processing time*: Duration from the controller receiving a message to the start of sending a message back ($t3 - t2$).
- *Downlink time*: Duration from the controller sending a message to the device receiving it, calculated as $t4 - t3$.
- Total *response time*: Duration from the device sending a message to receiving a response, calculated as $t4 - t1$.

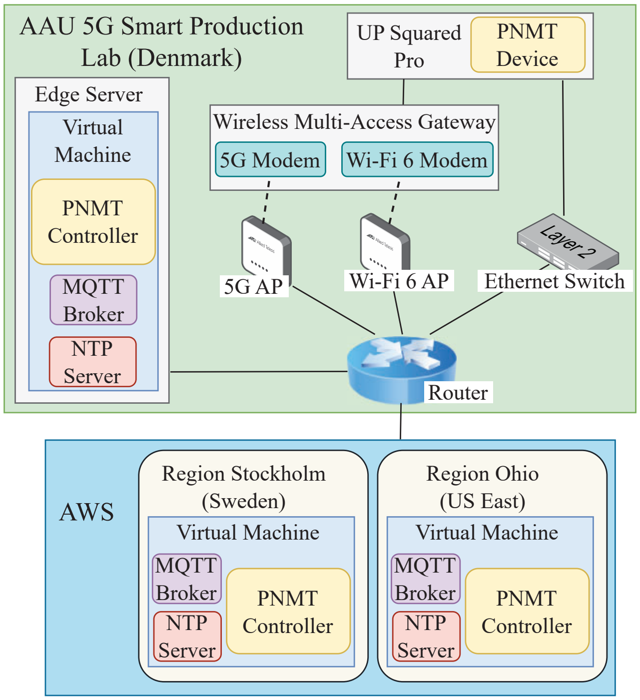

Fig. 2. System architecture for measurements.

We simulate the processing workload in Step (2) as a routine of summing the integer numbers from 1 to N, where N is a startup parameter. We use different values of N to evaluate the performance under varying processing workloads, as detailed in Subsection III-C.

We select the other measurement parameters to be consistent with real-world industrial practices. PNMTs use Quality of Service level 0 (QoS0) of MQTT, as demonstrated in the product documentation examples[1] of Pozyx real-time location system (RTLS). The uplink and downlink messages are shorter than 70 bytes, similar to the Pickit[2] robot vision product. The message period, or the time interval between two consecutive $t1$, is set to 100 ms, reflecting real-world industrial scenarios. Our practical tests demonstrate that this period effectively prevents collisions between AMRs and other moving objects without overloading network traffic. Additionally, Cominetti et al. [15] and the Pickit product documentation[2] both indicate that a message period of 100 ms is common in intelligent automation systems. Notably, if the response time in a loop exceeds 100 ms, this message period will be invalid, and the next $t1$ will coincide with the $t4$ of the current loop.

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[1] https://docs.pozyx.io/enterprise/mqtt-connection-info

[2] https://docs.pickit3d.com/en/3.4/robots/robot-brands/socket_communication.html

TABLE I
CPU DIFFERENCES BETWEEN EDGE AND CLOUDS VMS

Location CPU spec	Edge	AWS Stockholm	AWS Ohio
Model	Intel(R) Xeon(R) E5-2680 v4	Intel(R) Xeon(R) Platinum 8259CL	Intel(R) Xeon(R) E5-2676 v3
Clock speed (MHz)	2394.454	2499.996	2399.827
Cache size (KB)	16384	36608	30720

B. System Architecture and Infrastructure

Fig. 2 depicts the system architecture for our measurements. The PNMTs device runs on an UP Squared Pro[3] single-board computer located in our AAU 5G Smart Production Lab [2] in Denmark. We established three Virtual Machines (VMs): one on an edge server in our lab and the other two in different AWS regions. This setup allows us to measure the performance of edge and cloud servers located in different geographic regions by deploying the PNMTs controller on any of the three VMs. Each VM is configured with 1 CPU core and 1 GB of memory, limited by AWS Free Tier. However, as detailed in Table I, we observed differences in CPU specifications across the VMs, which may impact computational performance. An MQTT broker is deployed on each VM to enable MQTT communication. Additionally, each VM includes a Network Time Protocol (NTP) server for clock synchronization between the device and the controller, essential for calculating the performance metrics accurately.

As shown in Fig. 2, the device can access the controller through different network technologies, namely Ethernet, 5G, and Wi-Fi 6. The 5G network offers 100 MHz bandwidth and a 3/7 uplink/downlink Time Division Duplex (TDD) ratio. It leverages an in-house Nokia MXie 5G core[4] and three Radio Access Network (RAN) base stations, operating in Stand-Alone (SA) Rel. 15 mode. The Wi-Fi 6 network operates on the 5 GHz band with three CISCO MR36 Access Points (APs)[5], each configured at 20 MHz bandwidth and transmitting at 20 dBm. The UP Squared Pro connects to the 5G and Wi-Fi 6 networks via a Wireless multi-access gateway (WMAGW) [16] equipped with a Simcom SIM8262E-M2 5G modem[6] and an Intel AX200 Wi-Fi 6 modem[7] with the power-saving feature disabled. The WMAGW also supports a multi-connectivity approach, utilizing both 5G and Wi-Fi 6 networks concurrently. In this mode, the gateway duplicates each packet and transmits it through both networks simultaneously. When the router receives them, it keeps only the first duplicate and discards the second. We name this approach *Aalborg University Multi-Connectivity (AAU MC)* in our measurements.

C. Long-time and Shot-time Measurements

To assess the stability of the technologies, we conducted 9 long-time measurements on the following scenarios: "Ethernet, Edge", "5G, Edge", "Wi-Fi 6, Edge", "AAU MC, Edge", "Ethernet, AWS Stockholm", "5G, AWS Stockholm", "Wi-Fi 6, AWS Stockholm", "AAU MC, AWS Stockholm", and "Ethernet, AWS Ohio". In this context, "Ethernet, Edge" means deploying the controller in the VM on the edge server with the device using Ethernet to access the controller – the other configurations follow a similar pattern. Each long-time measurement lasted $39-45$ hours. During each measurement, Wireshark was employed to capture packets to facilitate a detailed analysis of network latencies. In all the long-time measurements, we fixed the PNMTs startup parameter N (introduced in Subsection III-A) to 1 to avoid too many scenarios. Thus, these measurements primarily focused on network propagation rather than workload processing.

To investigate the impact of varying processing workloads, we conducted 18 short-term measurements for the following scenarios: "Ethernet, Edge", "Ethernet, AWS Stockholm", and "Ethernet, AWS Ohio", using different N values: 1, 100, 10000, 100000, 250000, and 500000. Only Ethernet was used because network access methods do not affect workload processing. Each short-time measurement lasted $41-61$ seconds.

IV. RESULTS, ANALYSIS, AND RECOMMENDATIONS

A. Results of Long-time Measurements

1) Uplink Time: The uplink times in long-time measurements are presented in Fig. 3, and the data percentiles are detailed in Table II. As expected, "Ethernet, Edge" exhibits the shortest uplink times except for 2 outliers (caused by the MQTT broker, according to our analysis of the Wireshark traces). This configuration will serve as a baseline for evaluating the performance of the wireless technologies.

With the same network access methods, compared to edge scenarios, AWS Stockholm increases uplink times by $9.2-11.1$ ms for 99% of messages, while AWS Ohio shows an increase of $56.7-61.5$ ms due to its longer distance. For the remaining messages, the effects from these clouds are unstable due to the constantly changing network conditions of the Internet. Notably, about 0.2% of messages experience uplink times exceeding 171 ms in the "Ethernet, AWS Ohio" scenario. This is because the MQTT client performs a keepalive every minute, which blocks other messages. Normally, this keepalive takes place entirely during Step (4) of the PNMTs, but the

TABLE II
UPLINK TIME DISTRIBUTION PERCENTILES IN LONG-TIME MEASUREMENTS (N=1) (UNIT: MILLISECOND)

Percentile Scenario	50th	90th	99th	99.9th	99.99th	99.999th	100th
Ethernet, Edge	1.44	1.57	1.79	2.76	5.45	8.03	75.89
Ethernet, Stockholm	10.67	10.96	11.82	14.44	20.49	231.25	340.25
5G, Edge	5.76	7.1	9.06	12.33	17.51	420.08	437.93
5G, Stockholm	15.56	17.22	19.57	22.94	30.64	434.28	1921.87
Wi-Fi 6, Edge	2.11	2.42	3.09	12.01	62.52	70.64	76.42
Wi-Fi 6, Stockholm	12.89	13.18	14.18	23.36	73.28	82.07	421.59
AAU MC, Edge	2.77	3.31	4.94	6.86	8.52	11.33	14.74
AAU MC, Stockholm	12.8	13.09	14.49	18.35	23.06	32.87	72.28
Ethernet, Ohio	58.14	58.34	63.31	171.98	172.75	187.69	2752.58

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[3] https://up-board.org/up-squared-pro/

[4] https://www.dac.nokia.com/mx-industrial-edge/

[5] https://meraki.cisco.com/product/wi-fi/indoor-access-points/mr36/

[6] https://en.simcom.com/product/SIM8262X-M2.html

[7] https://www.intel.com/content/www/us/en/products/sku/189347/intel-wifi-6-ax200-gig/specifications.html

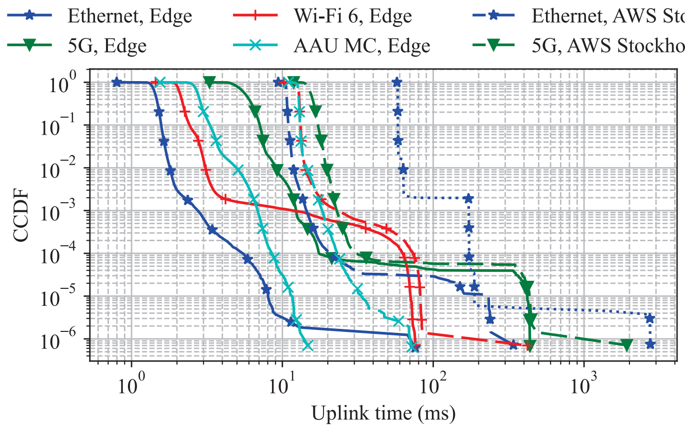

Fig. 3. Uplink time in long-time measurements (N=1).

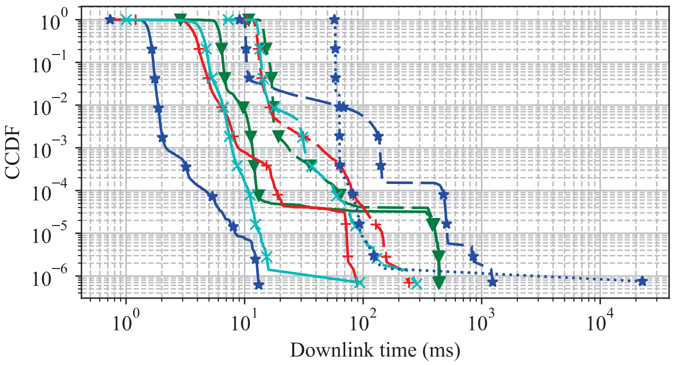

Fig. 4. Downlink time in long-time measurements (N=1).

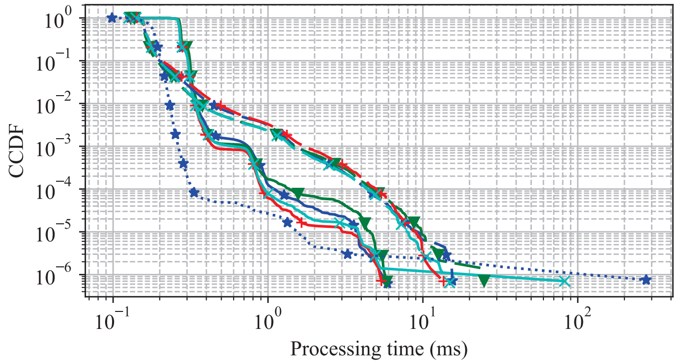

Fig. 5. Processing time in long-time measurements (N=1).

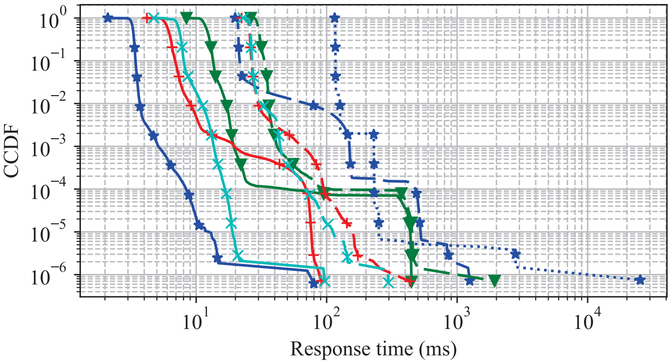

Fig. 6. Response time in long-time measurements (N=1).

response times exceeding 100 ms in the “Ethernet, AWS Ohio” scenario compress Step (4) to 0 ms, causing a blocking message every minute. Besides, both AWS Stockholm and AWS Ohio cause single and consecutive packet losses. However, MQTT uses Transmission Control Protocol (TCP), which remedies the packet losses through retransmissions, translating them into delays exceeding 200 ms.

Under the condition of AWS Stockholm or Edge, compared to Ethernet, 5G increases uplink times by $4.3 - 7.8$ ms for 99% of messages, while Wi-Fi 6 shows a lower increase of $0.7 - 2.4$ ms. However, Wi-Fi 6 introduces delays of less than 80 ms starting from the 99.99th percentile, while 5G causes delays exceeding 400 ms, but only starting from the 99.999th percentile. Since 5G’s 400 ms delays surpass the 200 ms[8] minimum TCP Retransmission Timeout (RTO) in Linux, they trigger superfluous TCP retransmissions.

AAU MC demonstrates superior stability compared to both 5G and Wi-Fi 6 individually, maintaining uplink times below 15 ms in “AAU MC, Edge”. This stability arises because a message in AAU MC experiences a delay only when both 5G and Wi-Fi 6 introduce delays concurrently, a rare occurrence. However, for 99.863% of messages, uplink times in “AAU MC, Edge” are approximately $1 - 2$ ms higher than those in “Wi-Fi 6, Edge”. We attribute this phenomenon to interactions with Linux network interfaces by the AAU MC programs. Interestingly, this phenomenon does not manifest in scenarios involving “AWS Stockholm”, potentially due to the unstable network conditions of the Internet.

2) Downlink Time: The downlink times in long-time measurements are presented in Fig. 4 and the data percentiles are detailed in Table III. The measured data reveal downlink characteristics similar to uplink:

- “Ethernet, Edge” exhibits the shortest delays.
- For most messages, AWS Ohio experiences higher delays compared to AWS Stockholm.
- The effects from clouds are unstable.
- Packet losses caused by clouds are translated into delays exceeding 200 ms by TCP retransmissions.
- Wi-Fi 6’s delays are shorter than 5G’s for most packets.
- 5G causes delays over 400 ms from the 99.999th percentile, resulting in superfluous TCP retransmissions.
- AAU MC shows better stability than 5G and Wi-Fi 6.
- For most messages, delays in “AAU MC, Edge” are slightly higher than those in “Wi-Fi 6, Edge”.

However, some downlink attributes differ from those of uplink. The MQTT keepalive does not affect downlink because the PNMTs controller is deployed on the same VM as the MQTT broker, eliminating the propagation time of the keepalive. Additionally, Wi-Fi 6’s high downlink times start from the 99.999th percentile instead of the 99.99th.

3) Processing Time: The processing times in long-time measurements are presented in Fig. 5. Network access methods do not affect processing time. At lower percentiles (50th, 90th), the processing times are in ascending order: “AWS

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[8] https://github.com/torvalds/linux/blob/8bb7eca972ad531c9b149c0a51ab43a417385813/include/net/tcp.h#L140

TABLE III
Downlink Time Distribution Percentiles in Long-Time Measurements (N=1) (Unit: Millisecond)

Percentile Scenario	50th	90th	99th	99.9th	99.99th	99.999th	100th
Ethernet, Edge	1.56	1.7	1.86	2.17	4.67	8.25	13.17
Ethernet, Stockholm	10.16	10.39	58.76	138.47	467.59	511.18	1237.42
5G, Edge	6.13	6.57	9.46	11.63	12.68	404.35	434.38
5G, Stockholm	14.51	16.19	17.34	23.4	61.06	404.47	442.55
Wi-Fi 6, Edge	3.72	4.42	6.24	8.85	18.48	72.25	88.47
Wi-Fi 6, Stockholm	12.59	13.37	16.11	43.51	80.36	143.41	243.69
AAU MC, Edge	4.35	4.96	6.56	7.8	10.82	13.17	93.62
AAU MC, Stockholm	13.05	13.75	16.52	31.82	56.51	94.19	283.64
Ethernet, Ohio	57.98	58.42	63.09	63.24	78.04	94.54	22681.69

TABLE IV
Response Time Distribution Percentiles in Long-Time Measurements (N=1) (Unit: Millisecond)

Percentile Scenario	50th	90th	99th	99.9th	99.99th	99.999th	100th
Ethernet, Edge	3.29	3.43	3.69	5.13	8.37	11.71	79.77
Ethernet, Stockholm	21	21.55	69.84	149.31	478.64	522.77	1248.78
5G, Edge	12.16	13.46	16.97	19.41	48.32	435.15	446.94
5G, Stockholm	30.2	33.3	35.99	41.69	104.92	450.59	1936.56
Wi-Fi 6, Edge	6.15	6.89	8.96	19.44	69.43	76.02	90.87
Wi-Fi 6, Stockholm	25.65	26.52	29.84	64.87	94.98	157.57	433.61
AAU MC, Edge	7.43	8.02	11.01	13.65	16.66	18.87	96.68
AAU MC, Stockholm	26.05	26.85	31.72	44.02	69.85	110.86	297.28
Ethernet, Ohio	116.32	116.8	126.6	230.17	231.4	251	25321.25

Stockholm < AWS Ohio < Edge”. At higher percentiles (99th, 99.9th, 99.99th, 99.999th), the order changes to “AWS Ohio < Edge < AWS Stockholm”. Since the three VMs have the same amounts of computational resources (1 CPU core and 1 GB of memory), we attribute this difference to the differences in CPU specifications shown in Table I. Besides, at the 100th percentile, there is an outlier of 82.22 ms in the “AAU MC, Edge” scenario, and two outliers of 34.5 ms and 276.56 ms in the “Ethernet, Ohio” scenario.

4) Response Time: The response times in long-time measurements are presented in Fig. 6 and the data percentiles are detailed in Table IV. With a minimal processing workload (the PNMTs startup parameter $N = 1$), response times are primarily influenced by uplink and downlink times, sharing all characteristics listed in Subsection IV-A2. Additionally, Wi-Fi 6 causes high response times starting from the 99.99th percentile.

B. Results of Short-time Measurements

The varying processing workloads in short-time measurements do not impact uplink or downlink times, so we focus exclusively on processing and response times.

1) Processing Time: The processing times in short-time measurements are presented in Fig. 7 and the data percentiles are detailed in Table V. Key observations include:

- Processing time increases with workload.
- Across all tested values of N, AWS Ohio demonstrates the shortest processing times in nearly all listed percentiles.
- For most tested N values, AWS Stockholm outperforms Edge at lower percentiles, while Edge outpaces AWS Stockholm at higher percentiles.
- The effectiveness of AWS Stockholm worsens as workload increases. For instance, at $N = 1$, AWS Stockholm’s processing times are shorter than Edge’s from the 0th to 99.6th percentiles; at $N = 100000$, AWS Stockholm performs better from the 0th to 89.4th percentiles; at $N = 500000$, AWS Stockholm maintains its advantage from the 0th to 63.2th percentiles.

These variations in computational performance may stem from differences in CPU specifications detailed in Table I.

2) Response Time: The response times in short-time measurements are presented in Fig. 8. Despite AWS Ohio demonstrating a distinct advantage in processing times, the response times strictly adhere to the ascending order: “Edge < AWS Stockholm < AWS Ohio”. This indicates that even when calculating the sum of integers from 1 to 500000, the impact of computational performance disparities remains overshadowed by differences in network propagation times attributable to geographical locations.

C. Recommendations for Technology Selection

When selecting between 5G and Wi-Fi 6, applications with stringent response time requirements below 69.43 ms at the 99.99th percentile should prioritize 5G. For applications that cannot tolerate occasional delays exceeding 400 ms at the 99.999th and 100th percentiles, Wi-Fi 6 is recommended.

For tasks with computational workloads equivalent to calculating the sum of integers from 1 to 500000 or less, if equal computational resources (e.g., CPU and memory) are available at both the edge and clouds, we recommend using edge computing. Under these conditions, clouds do not offer shorter response times.

TCP-based protocols like MQTT can be used to remedy packet losses caused by clouds, but we recommend disabling MQTT keepalive in scenarios with short message periods to avoid blocking messages. In our measurements, 5G and Wi-

TABLE V
Processing Time Distribution Percentiles in Short-Time Measurements Using Ethernet (Unit: Millisecond)

Percentile Scenario	50th	90th	99th	99.9th	99.99th	99.999th	100th
Edge, N=1	0.28	0.74	0.82	0.92	0.92	0.92	0.93
Edge, N=100	0.29	0.77	0.82	1.21	1.43	1.45	1.46
Edge, N=10000	1.92	1.97	2.18	4.09	4.3	4.32	4.33
Edge, N=100000	10.99	12.07	12.48	12.99	13.05	13.05	13.05
Edge, N=250000	20.99	21.63	22.95	26.03	27.68	27.84	27.86
Edge, N=500000	36.35	37.22	38.41	48.28	54.33	54.93	55
Stockholm, N=1	0.17	0.36	0.49	1.55	2.07	2.12	2.13
Stockholm, N=100	0.34	0.46	0.8	1.27	1.35	1.36	1.36
Stockholm, N=10000	0.99	1.24	2.43	3.13	3.26	3.27	3.27
Stockholm, N=100000	7.52	12.23	18.8	25.07	27.33	27.55	27.58
Stockholm, N=250000	18.4	27.86	40.99	55.49	57.49	57.69	57.71
Stockholm, N=500000	34.35	47.72	68.85	78.06	80.36	80.59	80.62
Ohio, N=1	0.19	0.21	0.22	0.23	0.23	0.23	0.23
Ohio, N=100	0.2	0.21	0.24	0.27	0.27	0.27	0.27
Ohio, N=10000	1.01	1.05	1.11	1.15	1.15	1.15	1.15
Ohio, N=100000	6.3	6.52	7.74	9.16	10	10.08	10.09
Ohio, N=250000	14.39	14.73	15.89	20.14	20.9	20.98	20.98
Ohio, N=500000	29.09	30.09	32.33	34.53	35.3	35.38	35.39

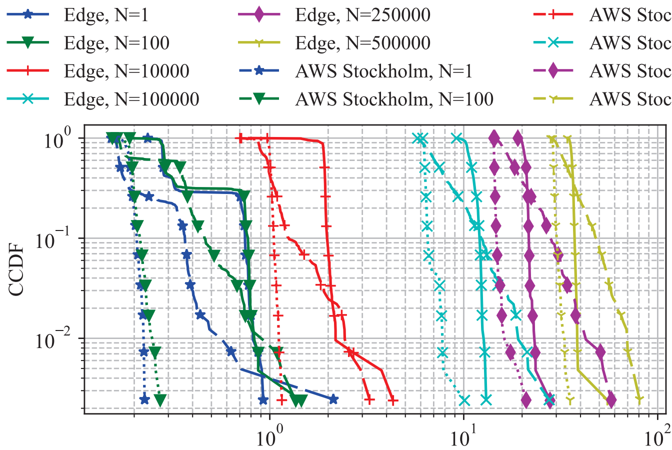

Fig. 7. Processing time in short-time measurements using Ethernet.

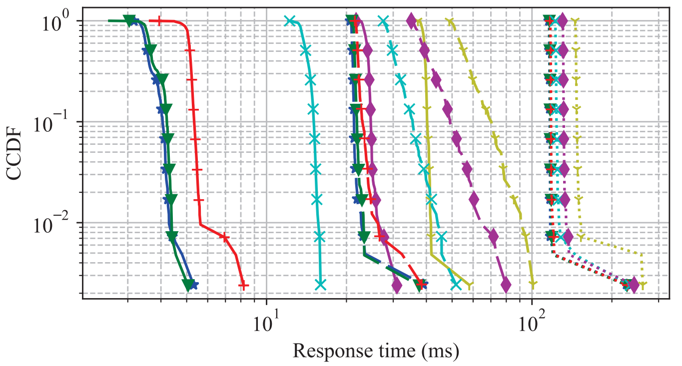

Fig. 8. Response time in short-time measurements using Ethernet.

Fi 6 did not expose packet losses to higher layers. Therefore, in scenarios combining edge computing with 5G or Wi-Fi 6, we recommend using User Datagram Protocol (UDP)-based protocols to avoid unnecessary packets such as acknowledgments and retransmissions.

V. CONCLUSION

This paper presents our measurements and analysis of MQTT response times in cloud and edge computing across various network access methods. Our results indicate that 5G and Wi-Fi 6 each have unique advantages at different percentiles. Additionally, we observe that not all clouds outperform edge computing in terms of computational performance, while they all result in higher network propagation times. The choice between these technologies should depend on the Quality of Service (QoS) requirements and processing workloads of applications, as well as the available computational resources of edge and cloud servers.

However, at the current stage, we recognize the limitations of our study. First, due to constraints imposed by the AWS Free Tier, we only measured the computational performance using a single CPU core. Future work should include parallel computing with multiple CPU cores. Second, the processing workload in PNMTs was to calculate a sum of integers, which is relatively simple compared to real-world production tasks. Future studies should incorporate more complex workloads, such as Machine learning (ML) processing. Besides, we plan to include different multi-connectivity implementations in our future measurements.

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