Test Study: Evaluating GPU and CPU impact on desktop editing workflows

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Evaluating GPU and CPU impact on desktop editing workflows

This test study was designed and conducted to examine the quantitative impact of hardware choices on the performance and user experience of ArcGIS Pro editing workflows. The intent was to develop design guidance that leads to an improved user experience, while balancing return on investment with the cost of hardware. Workflows were tested against a Network Information Management System hosted in Amazon Web Services (AWS) cloud infrastructure using AWS EC2 instances.

Note:

This test study is not intended to recommend specific virtual machine sizes or types. Rather, it shows that by adjusting hardware resources and observing the results, a system can be tuned to increase the amount of work staff can do while improving their experience, increasing return on investment. However, adding more hardware resources without understanding the impact may not deliver the expected results and should be avoided.

Tested workflows

To ensure the test study provides valid results, the workflows need to represent real user experiences and the actual steps that users will take in interacting with the system. The editing workflows used in this test study represent some of the foundational activities required to maintain an as-built gas network. The contents of the workflows were defined by working with experienced staff and Esri customer feedback to identify the specific steps, sequencing and type of activities involved in each workflow. The following four key workflows were run manually against the system under load to capture user experience and overall performance:

1. Create a new service – a new customer gas service
2. Remove a service –abandoning a customer gas service
3. Extend a main – adding a distribution pipe to the network
4. Replace a main – modifying terminal connections for gas pipes

You can read more about these workflows in the related system test study which evaluated a specific system configuration of a Network Information Management System reference architecture.

Hardware choices

ArcGIS systems that are business and/or mission-critical have requirements that generally include:

- Minimal system downtime due to expected or unexpected events
- Excellent service performance, without substantial lag that would hinder end-user productivity
- An efficient, effective, and overall positive end-user experience

While there are many design considerations that contribute to the achievement of these requirements, this test study focuses specifically on the impact of CPUs and GPU-enabled client hardware on the performance and user experience of ArcGIS Pro utility network information management editing workflows.

GPU

A GPU, or Graphics Processing Unit, is a specialized hardware component that can improve processing efficiency for many compute-intensive tasks. For ArcGIS Pro, using a configuration that is not GPU-enabled can result in CPU emulation of GPU capabilities, which can cause suboptimal performance for workflows that depend on graphics processing.

Most major cloud providers provide access to GPUs through various virtual machine (VM) offerings. However, it is important to check the compatibility matrix provided by the virtualization software vendor and Esri.

Learn more about GPU hardware selection.

CPU

A CPU, or Central Processing Unit, is a server's core computational unit. The amount and quality of CPU resources required is dependent on specific workloads. Usage patterns collected through appropriate telemetry capture and monitoring practices can help identify bottlenecks and determine whether acceptable utilization thresholds are exceeded. This might signal that an increase in CPU allocation is needed.

When operating ArcGIS in the cloud, like AWS, Azure, and GCP, it is important to understand the ratio of virtual CPU (vCPU) to physical CPU when making hardware choices so that system components

may be assigned appropriate resources. There is a 2:1 ratio of vCPU:CPU for all instances used in this test study, but some virtualization options may have different ratios, such as 1:1.

Test results

Testing was conducted to examine how different hardware selections would impact editing workflow performance and user experience. Desktops were monitored as workflows were conducted under load.

Scripted testing was performed to simulate the steps an editor would take when performing the defined workflows. To provide meaningful results, all the system hardware and configuration (other than the desktop instances being tested) was held constant.

Upon test completion, results were assembled and analyzed to compare desktop utilization and end-user efficiency with different hardware configurations.

Impact of GPU configuration on desktop editing workflows

The following client configurations were used to compare the impact of a GPU on performance and user experience of the editing workflows on ArcGIS Pro:

- An Amazon EC2 R5XL instance (no GPU)
- An Amazon EC2 G4DNXL instance (GPU-enabled)

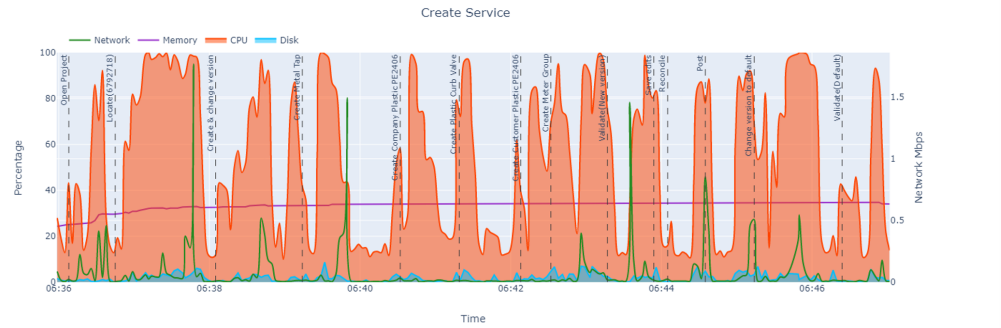
There are two sets of summarized results for each instance configuration (without GPU and with GPU) under each workflow.

Create a service

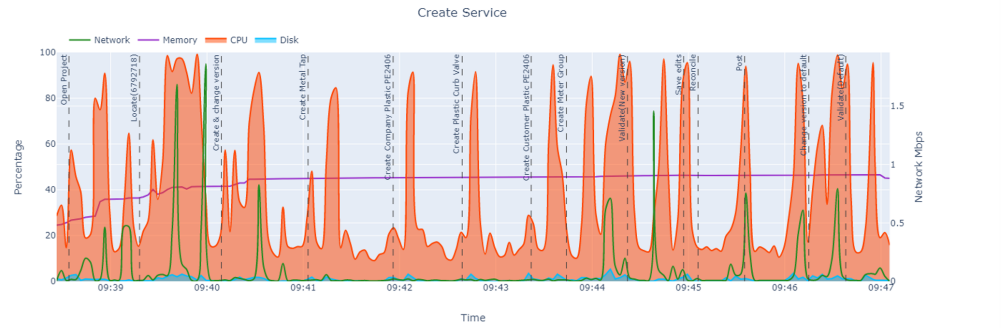
In this workflow, a new gas service endpoint was added to the network.

1. **Without GPU**
    - ArcGIS Pro 3.1 - Amazon EC2 R5XL instance (2 CPU / 4vCPU, 32 GB RAM)
    - Workflow duration: 9.7 minutes
    - Average CPU utilization: 48%

- Average memory utilization: 8 GB



2. **With GPU**
    - ArcGIS Pro 3.1 - Amazon EC2 G4DNXL instance (2 CPU / 4vCPU, 16 GB RAM, GPU - 16GB)
    - Workflow duration: 8.5 minutes - reduced by 1.2 minutes (12%)
    - Average CPU utilization: 38% - reduced by 21%
    - Average memory utilization: 6.7 GB - reduced by 16%

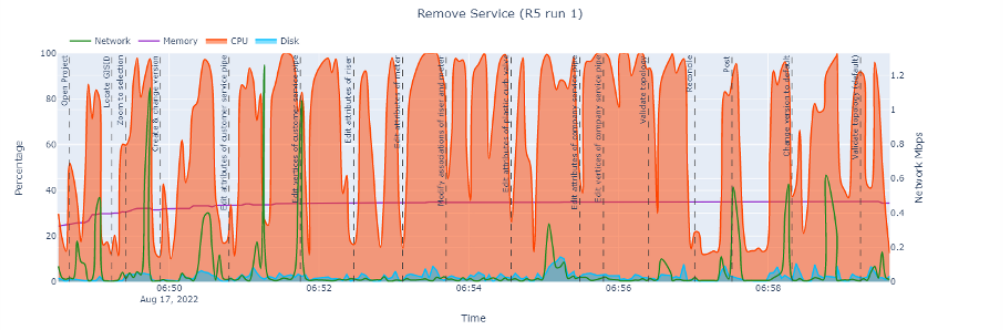


Remove a service

In this workflow, a new gas service endpoint was removed from the network.

1. **Without GPU**
    - ArcGIS Pro 3.1 - Amazon EC2 R5XL instance (2 CPU / 4vCPU, 32 GB RAM)
    - Workflow duration: 11.7 minutes
    - Average CPU utilization: 58%

- Average memory utilization: 8.1 GB



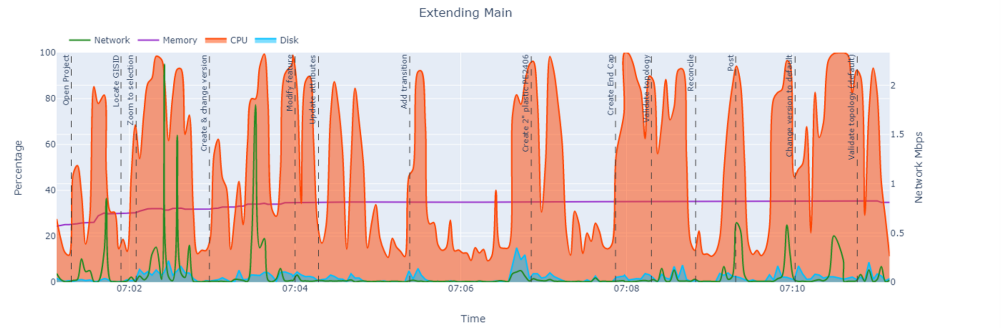
2. **With GPU**
    - ArcGIS Pro 3.1 - Amazon EC2 G4DNXL instance (2 CPU / 4vCPU, 16 GB RAM, GPU - 16GB)
    - Workflow duration: 9.0 minutes - reduced by 2.7 minutes (23%)
    - Average CPU utilization: 45% - reduced by 22%
    - Average memory utilization: 6.8 GB - reduced by 16%

Extend a main

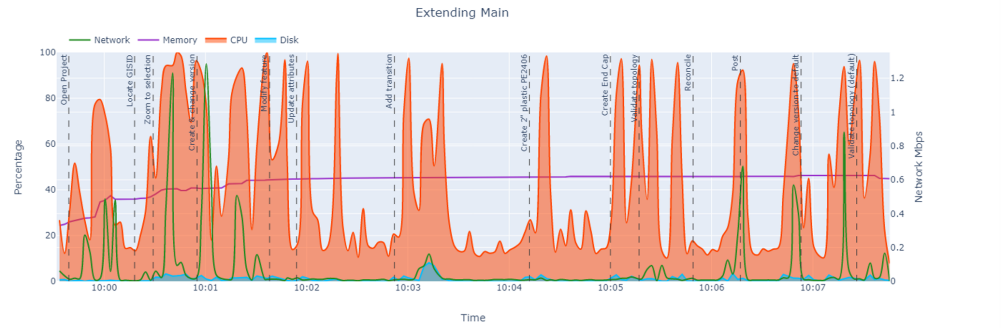
In this workflow, a distribution pipe was added to the network.

1. **Without GPU**
    - ArcGIS Pro 3.1 - Amazon EC2 R5XL instance (2 CPU / 4vCPU, 32 GB RAM)
    - Workflow duration: 10.0 minutes
    - Average CPU utilization: 46%

- Average memory utilization: 8.1 GB



2. **With GPU**
    - ArcGIS Pro 3.1 - Amazon EC2 G4DNXL instance (2 CPU / 4vCPU, 16 GB RAM, GPU - 16GB)
    - Workflow duration: 8.5 minutes – reduced by 1.5 minutes (15%)
    - Average CPU utilization: 39% - reduced by 15%
    - Average memory utilization: 6.8 GB - reduced by 16%

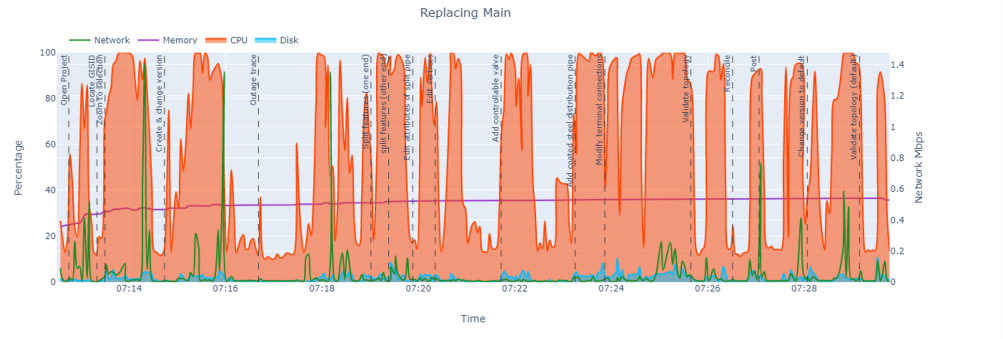


Replace a main

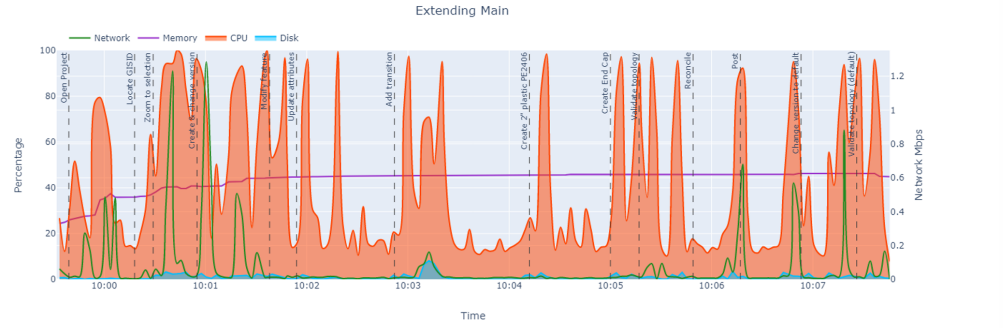
In this workflow, terminal connections were modified for a gas pipe.

1. **Without GPU**
    - ArcGIS Pro 3.1 - Amazon EC2 R5XL instance (2 CPU / 4vCPU, 32 GB RAM)
    - Workflow duration: 16.0 minutes
    - Average CPU utilization: 50%

- Average memory utilization: 8.4 GB

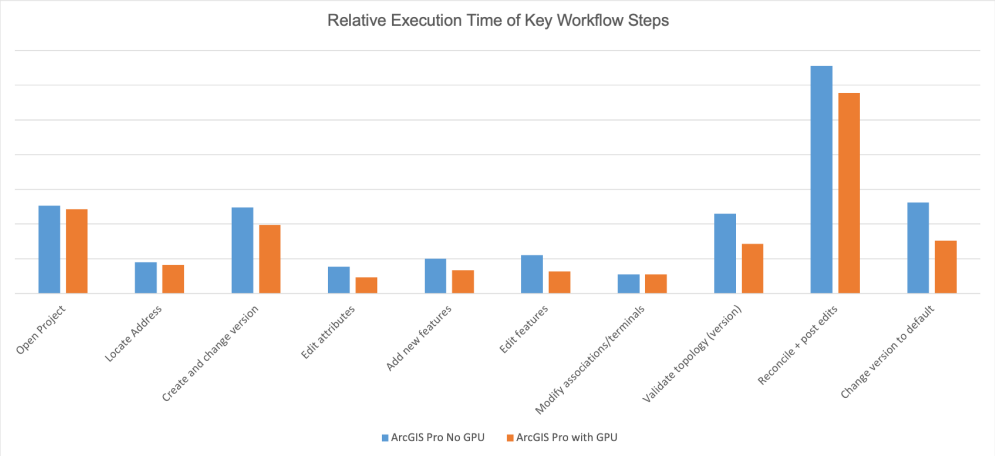


2. **With GPU**
    - ArcGIS Pro 3.1 - Amazon EC2 G4DNXL instance (2 CPU / 4vCPU, 16 GB RAM, GPU - 16GB)
    - Workflow duration: 12.8 minutes - reduced by 3.2 minutes (20%)
    - Average CPU utilization: 28% - reduced by 44%
    - Average memory utilization: 7.1 GB - reduced by 15%



GPU workflow step times

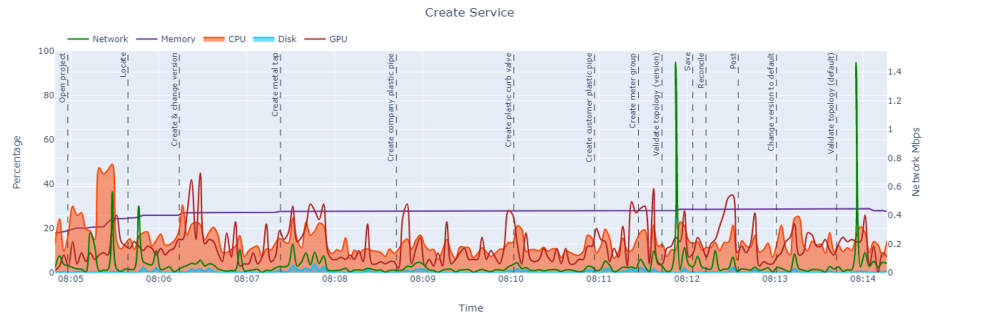
While the system was under load, conducted workflow times across key workflow steps were captured. This represents the average time it took to complete a given step for both the instances with and without a GPU. Most steps are notably faster with a GPU enabled machine.



Beyond these key steps, the results across all workflows show a GPU-enabled instance is 20% faster and it provides a better user experience, improving the return on investment.

Conclusions for impact of GPU configuration

The R5XL instance (no GPU) experienced more events and wider peaks at 100% CPU utilization. In the GPU-enabled instance (G4DNXL), the GPU handled some of the processing, offloading work from the CPU. The workflow duration was shorter because the user was not waiting for the CPU. Additionally, the tests revealed a reduction in memory utilization with the G4DNXL instance as compared to the R5XL instance. This could be because the operating system needed to use additional memory as part of the GPU emulation processing.



The graph above shows the GPU (red line) handling some of the load as compared to CPU usage (orange area). The GPU was busy and sometimes exceeded the CPU usage, presumably during map rendering. This reduced the load on the CPU, provided a better user experience, and improved workflow times, as it was 19% faster across all workflows performed in this test.

Impact of CPU configuration on desktop editing workflows

The following client configurations were used to compare the impact of increasing desktops from 2 CPU/4 vCPU to 4 CPU/8 vCPU on performance and user experience of the editing workflows on ArcGIS Pro 2.9.5.

- An Amazon EC2 G4DN.XL instance (2 CPU/4 vCPU)
- An Amazon EC2 G4DN.2XL instance (4 CPU/8 vCPU)

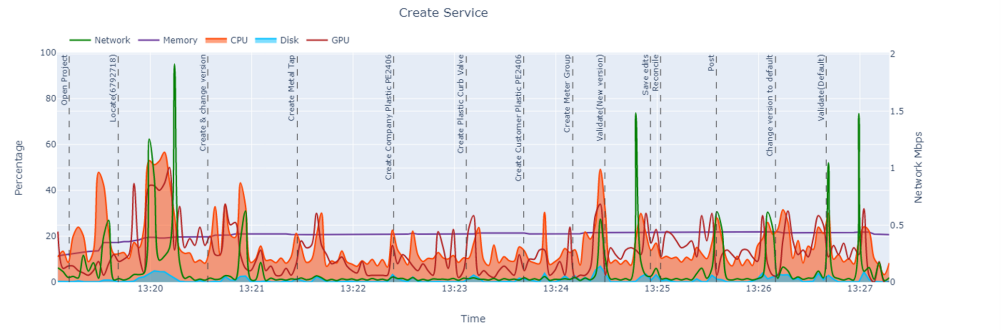
Create a service

In this workflow, a customer gas service endpoint was added to the network.

1. **4 vCPU**
    - ArcGIS Pro 2.9.5 – Amazon EC2 G4DN.XL instance (4 vCPU, 16 GB RAM, GPU-16GB)
    - Average workflow duration: 8.2 minutes
    - Average CPU utilization: 41%
    - Average memory utilization: 6.7 GB

2. **8 vCPU**
    - ArcGIS Pro 2.9.5 – Amazon EC2 G4DN.2XL instance (8 vCPU, 16 GB RAM, GPU-16GB)
    - Average workflow duration: 7.8 minutes – reduced by 0.4 minutes (4%)
    - Average CPU utilization: 16% - reduced by 61%

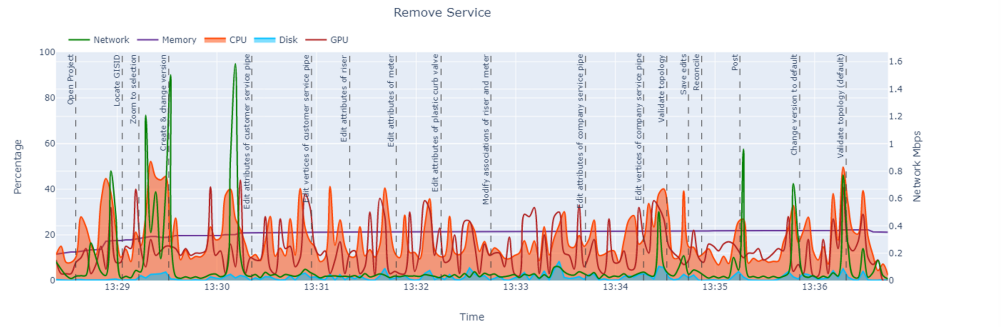
- Average memory utilization: 6.6 GB – reduced by 1.5%



Remove a service

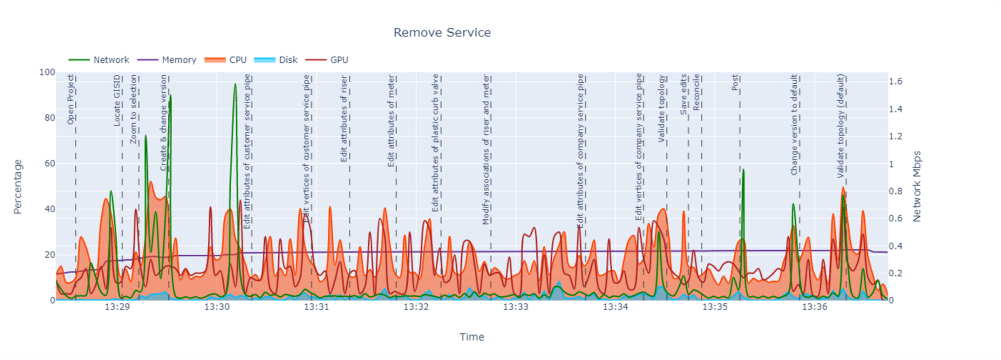
In this workflow, a customer gas service pipe was removed from the network.

1. **4 vCPU**
   - ArcGIS Pro 2.9.5 – Amazon EC2 G4DNXL instance (4 vCPU, 16 GB RAM, GPU-16GB)
   - Average workflow duration: 8.7 minutes
   - Average CPU utilization: 48.3%
   - Average memory utilization: 6.7 GB



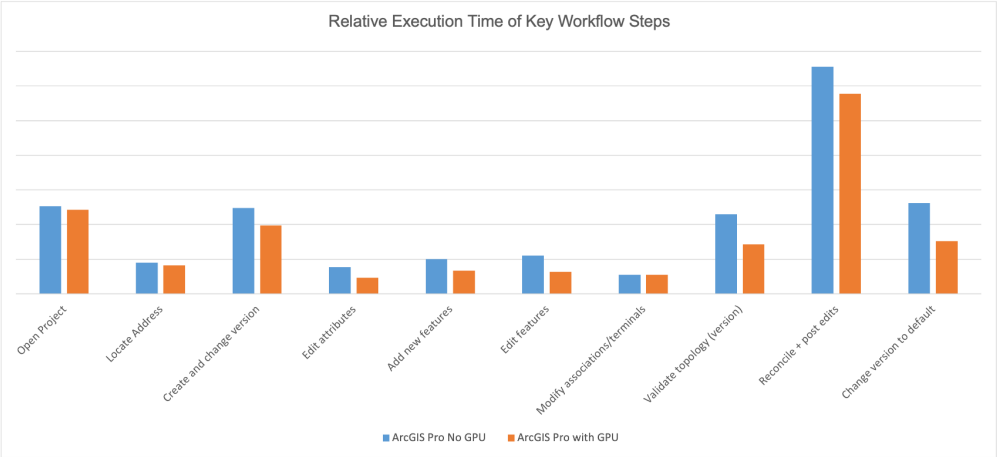
2. **8 vCPU**
   - ArcGIS Pro 2.9.5 – Amazon EC2 G4DN.2XL instance (8 vCPU, 16 GB RAM, GPU-16GB)
   - Average workflow duration: 7.9 minutes – reduced by 0.8 minutes (9%)
   - Average CPU utilization: 18.6% - reduced by 60%

- Average memory utilization: 6.6 GB – reduced by 1.5%



CPU workflow step times

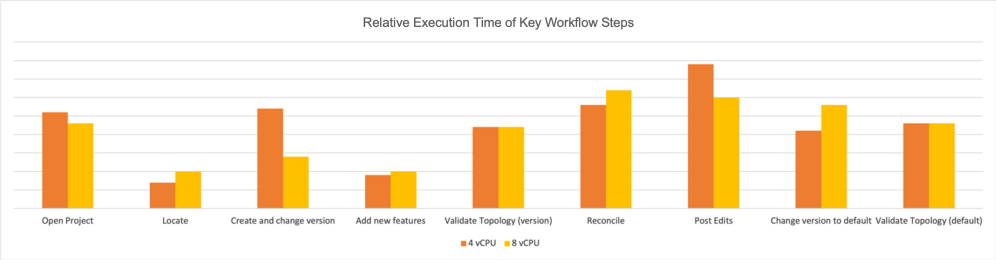
While the system was under load, conducted workflow times across key workflow steps were captured. They represent the average time it took to complete a given step for both instance sizes.



Conclusions for CPU configuration

Beyond the key steps, we looked at the total time for all steps in the four workflows tested. We observed that when increasing the instance size from 2CPU/4vCPU to 4CPU/8vCPU, the total time was 10% faster. One explanation for that result is the CPU usage shown in the chart below. Doubling the CPU allows ArcGIS Pro to further parallelize processing and improve overall processing efficiency, which reduced the average usage by an average of 63% across all workflows.

Test results



Conclusions and key takeaways

This test study is not intended to recommend specific instance sizes or types. Rather, it shows that by adjusting hardware resources and observing the results, a system can be tuned to increase the amount of work staff can do while improving their experience and increasing return on investment. However, adding more hardware resources without understanding the impact may not deliver the expected results.

Therefore, every organization should perform their own testing to evaluate the right hardware that effectively balances cost and performance for them, such as determining how much GPU is needed to support their workflows. Infrastructure needs change regularly, and routine testing should be done to optimize infrastructure investments.

Properly resourced desktop clients are essential to delivering a positive user experience, increasing editing efficiency, and increasing overall return on investment on your infrastructure. Therefore, make hardware choices that strike the balance between mitigating infrastructure expense (the cost of more robust instances) and operational expense (the cost of staff's time, business interruption, and opportunity cost). ArcGIS Pro desktops should be GPU-enabled and should be allocated sufficient CPU for the workload. Learn more about ArcGIS Pro virtualization and GPU hardware selection in the ArcGIS Architecture Center.

Key takeaways

- Under-resourcing ArcGIS Pro desktop instances will negatively impact end user experience and increase their execution times for desktop editing workflows.
- High CPU utilization is a contributing factor to poor user experience and increased workflow times.
- Increasing the number of CPUs from 2 to 4 (or 4 to 8 vCPU) reduced editing workflow execution time by 10%.
- GPU-enabled instances reduced editing workflow execution time by 19%.
- GPU-enabled instances reduced memory usage by about 15%.
- Tests revealed that adding a dedicated GPU and optimizing vCPU for ArcGIS Pro virtual machines significantly improved end-user productivity and produced a net reduction in cost when operational expenses (labor costs) are considered.