Queues and Command Buffers

Application

Vulkan: Overall Block Diagram

Instance

Physical Device

Logical Device

Queue

Instance

Physical Device

Logical Device

Queue

Logical Device

Queue

Logical Device

Queue

Logical Device

Queue

Logical Device

Queue

Command Buffer

Command Buffer

Command Buffer
Vulkan: a More Typical (and Simplified) Block Diagram

Application

Instance

Physical Device

Logical Device

Queue

Command Buffer

Command Buffer

Command Buffer

Vulkan Queues and Command Buffers

- Graphics commands are recorded in command buffers, e.g., `vkCmdDoSomething(cmdBuffer, ...);`
- You can have as many simultaneous Command Buffers as you want
- Each command buffer can be filled from a different thread
- Command Buffers record our commands, but no work takes place until a Command Buffer is submitted to a Queue
- We don’t create Queues – the Logical Device has them already
- Each Queue belongs to a Queue Family
- We don’t create Queue Families – the Physical Device already has them
Querying what Queue Families are Available

```c
uint32_t count;
vkGetPhysicalDeviceQueueFamilyProperties( IN PhysicalDevice, &count, OUT (VkQueueFamilyProperties *)nullptr );
VkQueueFamilyProperties *vqfp = new VkQueueFamilyProperties[ count ];
vkGetPhysicalDeviceQueueFamilyProperties( PhysicalDevice, &count, OUT &vqfp );
for( unsigned int i = 0; i < count; i++ )
{
    fprintf( FpDebug, "\t%d: Queue Family Count = %2d ; Graphics Compute Transfer\n", i, vqfp[i].queueCount );
    if( ( vqfp[i].queueFlags & VK_QUEUE_GRAPHICS_BIT ) != 0 )        fprintf( FpDebug, " Graphics\n" );
    if( ( vqfp[i].queueFlags & VK_QUEUE_COMPUTE_BIT  ) != 0 )        fprintf( FpDebug, " Compute\n" );
    if( ( vqfp[i].queueFlags & VK_QUEUE_TRANSFER_BIT ) != 0 )        fprintf( FpDebug, " Transfer\n" );
    fprintf(FpDebug, "\n");
}
```

Found 3 Queue Families:
0: Queue Family Count = 16 ; Graphics Compute Transfer
1: Queue Family Count =  1 ; Transfer
2: Queue Family Count =  8 ; Compute

Similarly, we Can Write a Function that Finds the Proper Queue Family

```c
int FindQueueFamilyThatDoesGraphics( )
{
    uint32_t count = -1;
vkGetPhysicalDeviceQueueFamilyProperties( IN PhysicalDevice, &count, OUT (VkQueueFamilyProperties *)nullptr );
VkQueueFamilyProperties *vqfp = new VkQueueFamilyProperties[ count ];
vkGetPhysicalDeviceQueueFamilyProperties( IN PhysicalDevice, &count, OUT vqfp );
for( unsigned int i = 0; i < count; i++ )
{
    if( ( vqfp[i].queueFlags & VK_QUEUE_GRAPHICS_BIT ) != 0 )
        return i;
}
return -1;
}
```

"These are not the Queue Families you're looking for."
float queuePriorities[] = {
  1.0f // one entry per queueCount
};

VkDeviceQueueCreateInfo vdqci[1];
vdqci.sType = VK_STRUCTURE_TYPE_QUEUE_CREATE_INFO;
vdqci.pNext = nullptr;
vdqci.flags = 0;
vdqci.queueFamilyIndex = FindQueueFamilyThatDoesGraphics();
vdqci.queueCount = 1;
vdqci.queuePriorities = (float *) queuePriorities;

VkDeviceCreateInfo vdci;
vdc.sType = VK_STRUCTURE_TYPE_DEVICE_CREATE_INFO;
vdc.pNext = nullptr;
vdc.flags = 0;
vdc.queueCreateInfoCount = 1; // # of device queues wanted
vdci.pQueueCreateInfos = &vdqci[0]; // array of VkDeviceQueueCreateInfo's
vdcc.enabledLayerCount = sizeof(myDeviceLayers) / sizeof(char *);
vdc.ppEnabledLayerNames = myDeviceLayers;
vdc.enabledExtensionCount = sizeof(myDeviceExtensions) / sizeof(char *);
vdc.ppEnabledExtensionNames = myDeviceExtensions;
vdc.pEnabledFeatures = IN &PhysicalDeviceFeatures; // already created

result = vkCreateLogicalDevice(PhysicalDevice, IN &vdci, PALLOCATOR, OUT &LogicalDevice);

VkQueue Queue;
uint32_t queueFamilyIndex = FindQueueFamilyThatDoesGraphics();
uint32_t queueIndex = 0;
result = vkGetDeviceQueue(LogicalDevice, queueFamilyIndex, queueIndex, OUT &Queue);

Creating a Logical Device Queue Needs to Know Queue Family Information

VkResult Init06CommandPool() {
  VkResult result;
  VkCommandPoolCreateInfo vcpci;
  vcpci.sType = VK_STRUCTURE_TYPE_COMMAND_POOL_CREATE_INFO;
  vcpci.pNext = nullptr;
  vcpici.flags = VK_COMMAND_POOL_CREATE_RESET_COMMAND_BUFFER_BIT | VK_COMMAND_POOL_CREATE_TRANSIENT_BIT;
#if defined CHOICES
  VK_COMMAND_POOL_CREATE_TRANSIENT_BIT
  VK_COMMAND_POOL_CREATE_RESET_COMMAND_BUFFER_BIT
#endif
  vcpici.queueFamilyIndex = FindQueueFamilyThatDoesGraphics();
  result = vkCreateCommandPool(LogicalDevice, IN &vcpici, PALLOCATOR, OUT &CommandPool);
  return result;
}
Creating the Command Buffers

```cpp
VkResult Init06CommandBuffers( )
{
    VkResult result;
    // allocate 2 command buffers for the double-buffered rendering:
    
    VkCommandBufferAllocateInfo vcbai;
    vcbai.sType = VK_STRUCTURE_TYPE_COMMAND_BUFFER_ALLOCATE_INFO;
    vcbai.pNext = nullptr;
    vcbai.commandPool = CommandPool;
    vcbai.level = VK_COMMAND_BUFFER_LEVEL_PRIMARY;
    vcbai.commandBufferCount = 2;           // 2, because of double-buffering
    result = vkAllocateCommandBuffers( LogicalDevice, IN &vcbai, OUT &CommandBuffers[0] );

    // allocate 1 command buffer for the transferring pixels from a staging buffer to a texture buffer:
    
    VkCommandBufferAllocateInfo vcbai;
    vcbai.sType = VK_STRUCTURE_TYPE_COMMAND_BUFFER_ALLOCATE_INFO;
    vcbai.pNext = nullptr;
    vcbai.commandPool = CommandPool;
    vcbai.level = VK_COMMAND_BUFFER_LEVEL_PRIMARY;
    vcbai.commandBufferCount = 1;
    result = vkAllocateCommandBuffers( LogicalDevice, IN &vcbai, OUT &TextureCommandBuffer );
    return result;
}
```

Beginning a Command Buffer

```cpp
VkSemaphoreCreateInfo vsci;
    vsci.sType = VK_STRUCTURE_TYPE_SEMAPHORE_CREATE_INFO;
    vsci.pNext = nullptr;
    vsci.flags = 0;
VkSemaphore imageReadySemaphore;
    result = vkCreateSemaphore( LogicalDevice, IN &vsci, PALLOCATOR, OUT &imageReadySemaphore );
    uint32_t nextImageIndex;
    vkAcquireNextImageKHR( LogicalDevice, IN SwapChain, IN UINT64_MAX, 
        IN imageReadySemaphore, IN VK_NULL_HANDLE, OUT &nextImageIndex );

VkCommandBufferBeginInfo vcbbi;
    vcbbi.sType = VK_STRUCTURE_TYPE_COMMAND_BUFFER_BEGIN_INFO;
    vcbbi.pNext = nullptr;
    vcbbi.flags = VK_COMMAND_BUFFER_USAGE_ONE_TIME_SUBMIT_BIT;
    vcbbi.pInheritanceInfo = (VkCommandBufferInheritanceInfo *)nullptr;
    result = vkBeginCommandBuffer( CommandBuffers[nextImageIndex], IN &vcbbi );
    . . .
    vkEndCommandBuffer( CommandBuffers[nextImageIndex] );
```
### Beginning a Command Buffer

- `vkBeginCommandBuffer()`
- `VkCommandBufferAllocateInfo`
- `vkCreateCommandBufferPool()`
These are the Commands that could be entered into the Command Buffer, II

vkCmdFillBuffer(commandBuffer, dstBuffer, dstOffset, size, data);
vkCmdNextSubpass(commandBuffer, contents);
vkCmdPipelineBarrier(commandBuffer, srcStageMask, dstStageMask, dependencyFlags, memoryBarrierCount, memoryBarriers);
vkCmdProcessCommandsNVX(commandBuffer, pProcessCommandsInfo);
vkCmdPushConstants(commandBuffer, pStageFlags, offset, size, pValues);
vkCmdPushDescriptorSetKHR(commandBuffer, pipelineBindPoint, layout, set, descriptorWriteCount, pDescriptorWrites);
vkCmdResetEvent(commandBuffer, stageMask);
vkCmdResolveImage(commandBuffer, srcImage, srcImageLayout, dstImage, dstImageLayout, regionCount, pRegions);
vkCmdSetBlendConstants(commandBuffer, blendConstants[4]);
vkCmdSetDepthBias(commandBuffer, depthBiasConstantFactor, depthBiasClamp, depthBiasSlopeFactor);
vkCmdSetDepthBounds(commandBuffer, minDepthBounds, maxDepthBounds);
vkCmdSetDeviceMaskKHX(commandBuffer, deviceMask);
vkCmdSetDiscardRectangleEXT(commandBuffer, firstDiscardRectangle, discardRectangleCount, pDiscardRectangles);
vkCmdSetEvent(commandBuffer, stageMask);
vkCmdSetLineWidth(commandBuffer, lineWidth);
vkCmdSetScissor(commandBuffer, firstScissor, scissorCount, pScissors);
vkCmdClearColorImageKHR(commandBuffer, framebuffer, colorAttachment, colorMask, clearColor);
vkCmdClearDepthStencilImageKHR(commandBuffer, framebuffer, depthAttachment, depthClearValue, depthWriteMask, stencilAttachment, stencilClearValue, stencilWriteMask);

These are the Commands that could be entered into the Command Buffer, II

VkResult
RenderScene() {
    VkResult result;
    VkSemaphoreCreateInfo vsci;
    vsci.sType = VK_STRUCTURE_TYPE_SEMAPHORE_CREATE_INFO;
    vsci.pNext = nullptr;
    vsci.flags = 0;
    VkSemaphore imageReadySemaphore;
    result = vkCreateSemaphore(LogicalDevice, IN &vsci, PALLOCATOR, OUT &imageReadySemaphore);
    uint32_t nextImageIndex;
    vkAcquireNextImageKHR(LogicalDevice, IN SwapChain, IN UINT64_MAX, IN VK_NULL_HANDLE, IN VK_NULL_HANDLE, OUT &nextImageIndex);
    VkCommandBufferBeginInfo vcbbi;
    vcbbi.sType = VK_STRUCTURE_TYPE_COMMAND_BUFFER_CREATE_INFO;
    vcbbi.pNext = nullptr;
    vcbbi.flags = 0;
    VkCommandBufferBeginInfoKHR vcbb;
    vcbb.sType = VK_STRUCTURE_TYPE_COMMAND_BUFFER_BEGIN_INFO_KHR;
    vcbb.pNext = nullptr;
    vcbb.flags = VK_COMMAND_BUFFER_USAGE_ONE_TIME_SUBMIT_BIT;
    result = vkBeginCommandBuffer(commandBuffers[nextImageIndex], IN &vcbbi);
VkClearColorValue vccv;
vccv<float32>[0] = 0.0;
vccv<float32>[1] = 0.0;
vccv<float32>[2] = 0.0;
vccv<float32>[3] = 1.0;

VkClearDepthStencilValue vcdsv;
vcdsv.depth = 1.f;
vcdsv.stencil = 0;

VkClearValue vcv[2];
vcv[0].color = vccv;
vcv[1].depthStencil = vcdsv;

VkOffset2D o2d = {0, 0};
VkExtent2D e2d = {Width, Height};
VkRect2D r2d = {o2d, e2d};

VkRenderPassBeginInfo vrpbi;
vrpbi.sType = VK_STRUCTURE_TYPE_RENDER_PASS_BEGIN_INFO;
vrpbi.pNext = nullptr;
vrpbi.renderPass = RenderPass;
vrpbi.framebuffer = Framebuffers[nextImageIndex];
vrpbi.renderArea = r2d;
vrpbi.clearValueCount = 2;
vrpbi.pClearValues = vcv;  // used for VK_ATTACHMENT_LOAD_OP_CLEAR

vkCmdBeginRenderPass(CommandBuffers[nextImageIndex], IN &vrpbi, IN VK_SUBPASS_CONTENTS_INLINE);

VkViewport viewport = {
    0.,                     // x
    0.,                     // y
    (float)Width,          // x
    (float)Height,         // y
    0.,                     // minDepth
    1.                      // maxDepth
};

vkCmdSetViewport(CommandBuffers[nextImageIndex], 0, 1, IN &viewport);         // 0=firstViewport, 1=viewportCount

VkRect2D scissor = {
    0,
    0,
    Width,
    Height
};

vkCmdSetScissor(CommandBuffers[nextImageIndex], 0, 1, IN &scissor);

vkCmdBindDescriptorSets(CommandBuffers[nextImageIndex], VK_PIPELINE_BIND_POINT_GRAPHICS,
                        GraphicsPipelineLayout, 0, 4, DescriptorSets, 0, (uint32_t*)nullptr);

VkBuffer buffers[1] = {MyVertexDataBuffer.buffer};
VkDeviceSize offsets[1] = {0};

vkCmdBindVertexBuffers(CommandBuffers[nextImageIndex], 0, 1, buffers, offsets);               // 0, 1 = firstBinding, bindingCount

const uint32_t vertexCount = sizeof(VertexData) / sizeof(VertexData[0]);
const uint32_t instanceCount = 1;
const uint32_t firstVertex = 0;
const uint32_t firstInstance = 0;

vkCmdDraw(CommandBuffers[nextImageIndex], vertexCount, instanceCount, firstVertex, firstInstance);

_vkEndCommandBuffer(CommandBuffers[nextImageIndex]);

_vkEndRenderPass(CommandBuffers[nextImageIndex]);
Submitting a Command Buffer to a Queue for Execution

```c
VkSubmitInfo vsi;
vsi.sType = VK_STRUCTURE_TYPE_SUBMIT_INFO;
vsi.pNext = nullptr;
vsi.commandBufferCount = 1;
vsi.pCommandBuffers = &CommandBuffer;
vsi.waitSemaphoreCount = 1;
vsi.pWaitSemaphores = imageReadySemaphore;
vsi.signalSemaphoreCount = 0;
vsi.pSignalSemaphores = (VkSemaphore *)nullptr;
vsi.pWaitDstStageMask = (VkPipelineStageFlags *)nullptr;
```

The Entire Submission / Wait / Display Process

1. **Create fence**
   - `VkFenceCreateInfo vfci;
     vfci.sType = VK_STRUCTURE_TYPE_FENCE_CREATE_INFO;
     vfci.pNext = nullptr;
     vfci.flags = 0;`  
   - `VkFence renderFence;`  
   - `vkCreateFence(LogicalDevice, &vfci, PALLOCATOR, OUT &renderFence);`  
   - `result = VK_SUCCESS;`  
2. **Get the queue**
   - `VkPipelineStageFlags waitAtBottom = VK_PIPELINE_STAGE_BOTTOM_OF_PIPE_BIT;`  
   - `VkQueue presentQueue;`  
   - `vkGetDeviceQueue(LogicalDevice, FindQueueFamilyThatDoesGraphics(), 0, OUT &presentQueue);`  
3. **Fill in the queue information**
   - `VkSubmitInfo vsi;
     vsi.sType = VK_STRUCTURE_TYPE_SUBMIT_INFO;
     vsi.pNext = nullptr;
     vsi.waitSemaphoreCount = 1;
     vsi.pWaitSemaphores = &imageReadySemaphore;
     vsi.pWaitDstStageMask = &waitAtBottom;
     vsi.commandBufferCount = 1;
     vsi.pCommandBuffers = &CommandBuffers[nextImageIndex];
     vsi.signalSemaphoreCount = 0;
     vsi.pSignalSemaphores = &SemaphoreRenderFinished;`  
4. **Submit the queue**
   - `result = vkQueueSubmit(presentQueue, 1, IN &vsi, IN renderFence);`  
   - `result = vkWaitForFences(LogicalDevice, 1, IN &renderFence, VK_TRUE, UINT64_MAX);`  
5. **Wait for the fence**
   - `vkDestroyFence(LogicalDevice, renderFence, PALLOCATOR);`  
6. **Display**
   - `VkPresentInfoKHR vpi;
     vpi.sType = VK_STRUCTURE_TYPE_PRESENT_INFO_KHR;
     vpi.pNext = nullptr;
     vpi.swapchainCount = 0;
     vpi.pSwapchains = (VkSwapchainKHR *)&SwapChain;
     vpi.imageIndex = nextImageIndex;
     vpi.pImageIndices = &nextImageIndex;
     vpi.pResults = (VkResult *)&results;`  
   - `result = vkQueuePresentKHR(presentQueue, IN &vpi);`