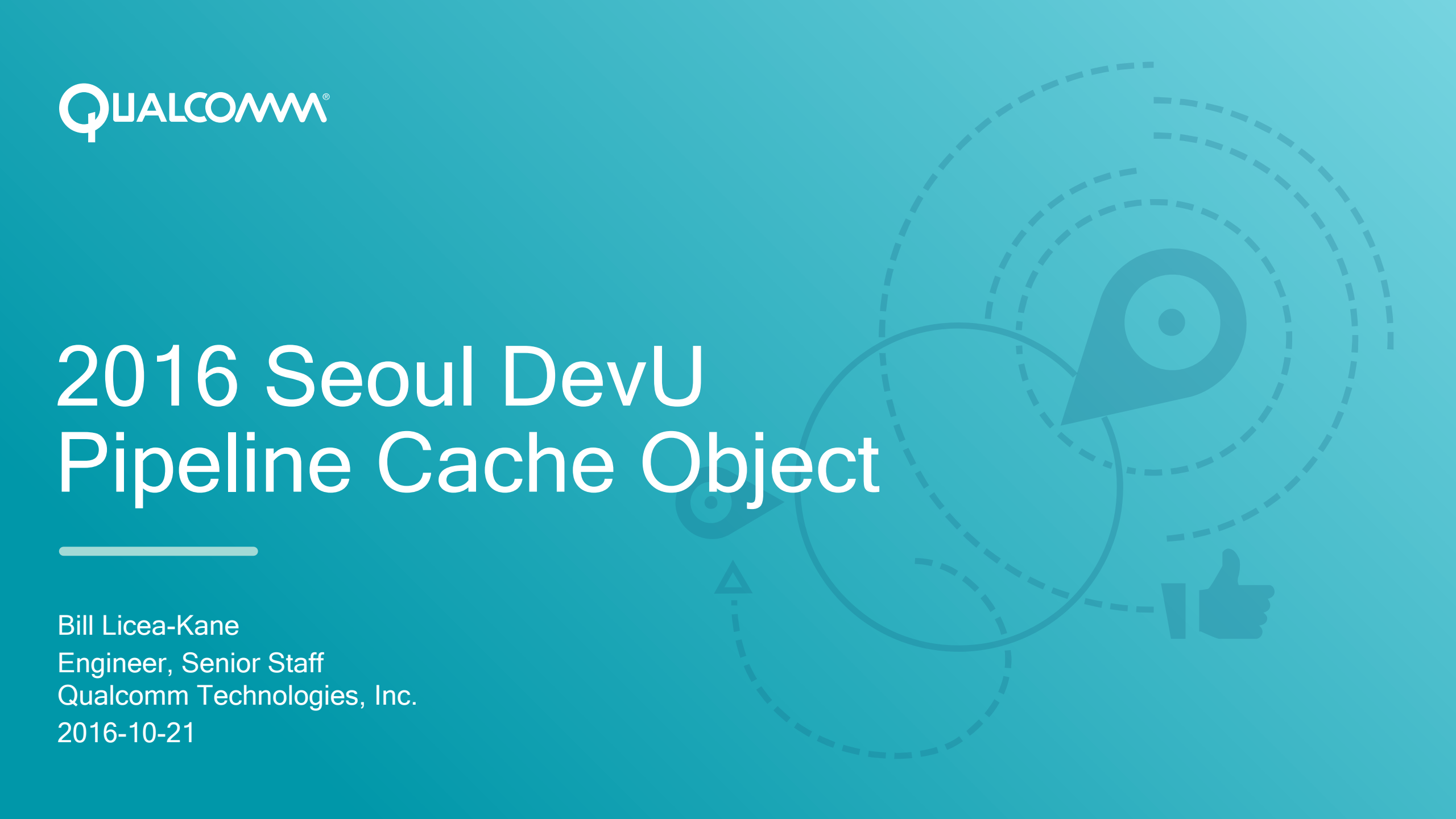

2016 Seoul DevU
Pipeline Cache Object

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Engineer, Senior Staff
Qualcomm Technologies, Inc.
2016-10-21

“Our application requires many many many Pipeline State Objects. Creation time is a huge issue!”

Create Pipeline State Objects Create Time Percentage

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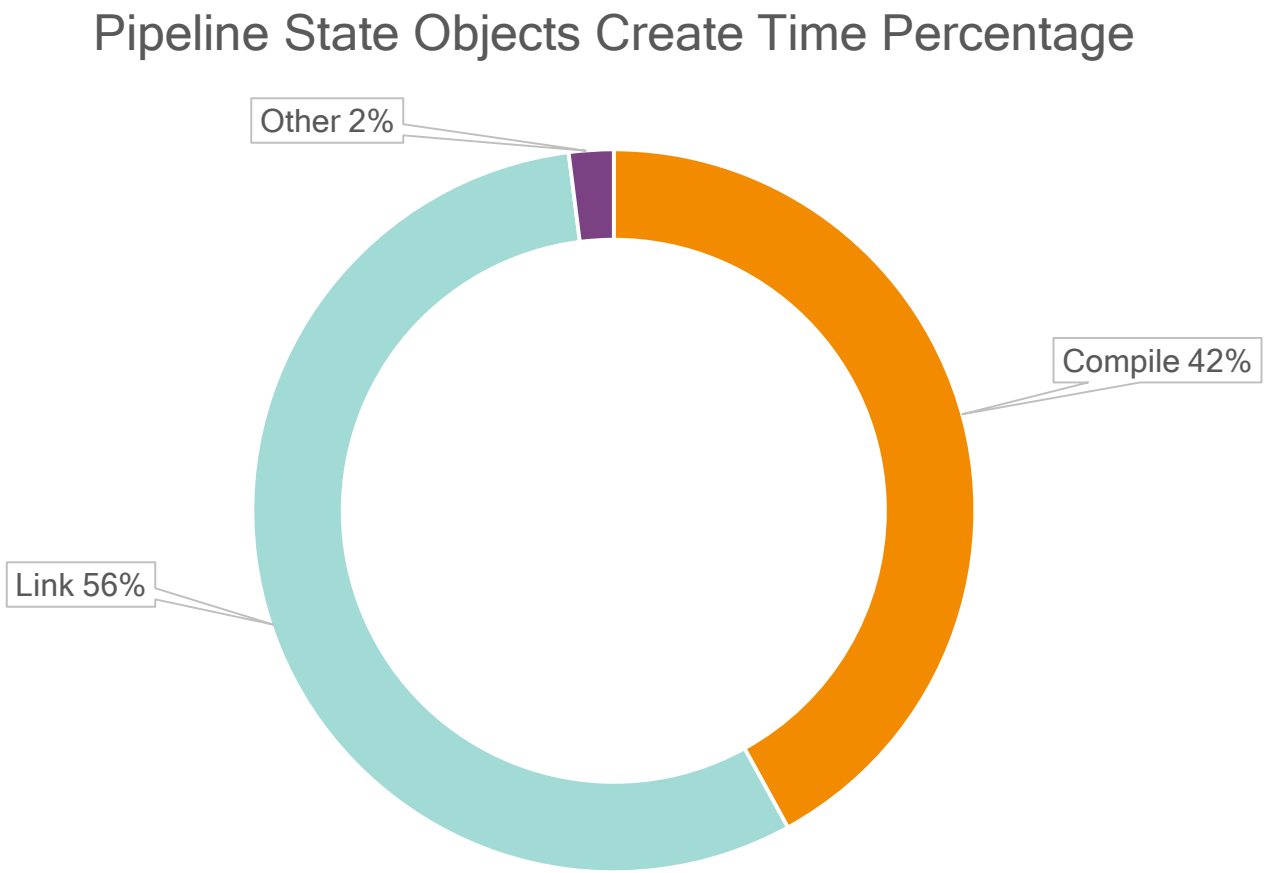

Compile and Link Redundancy

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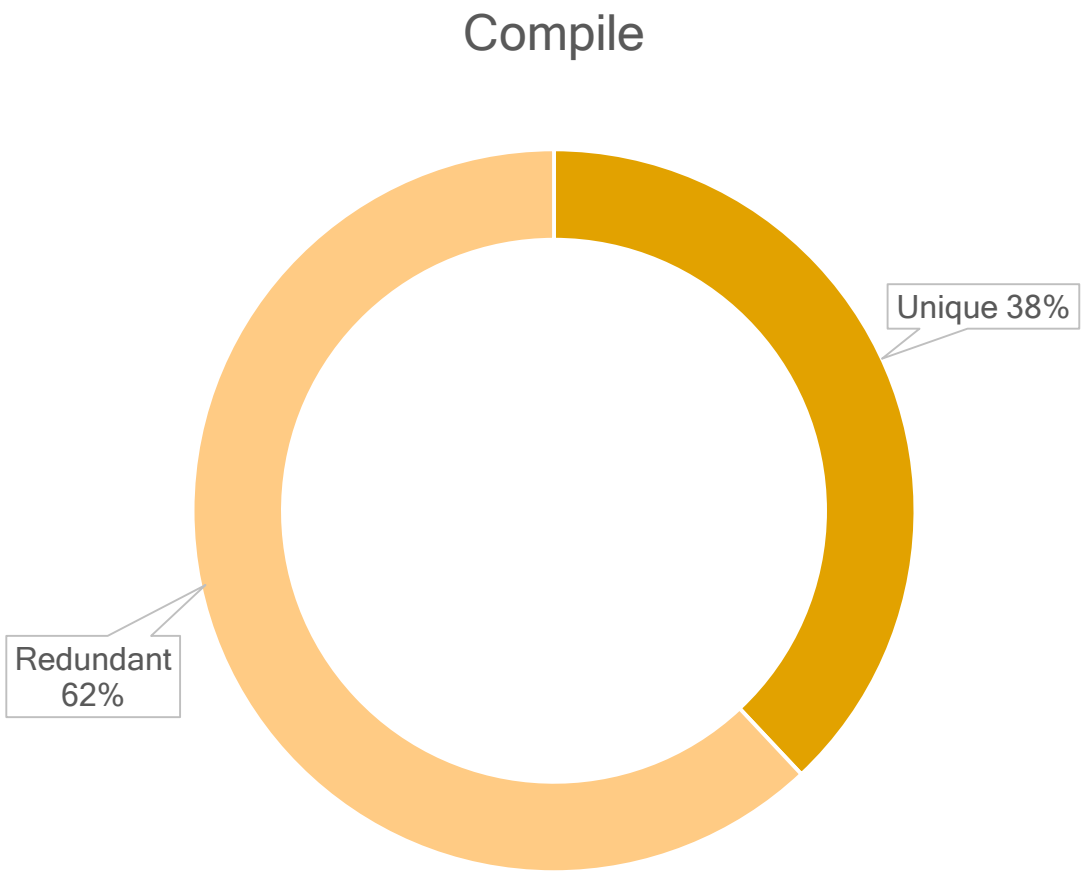

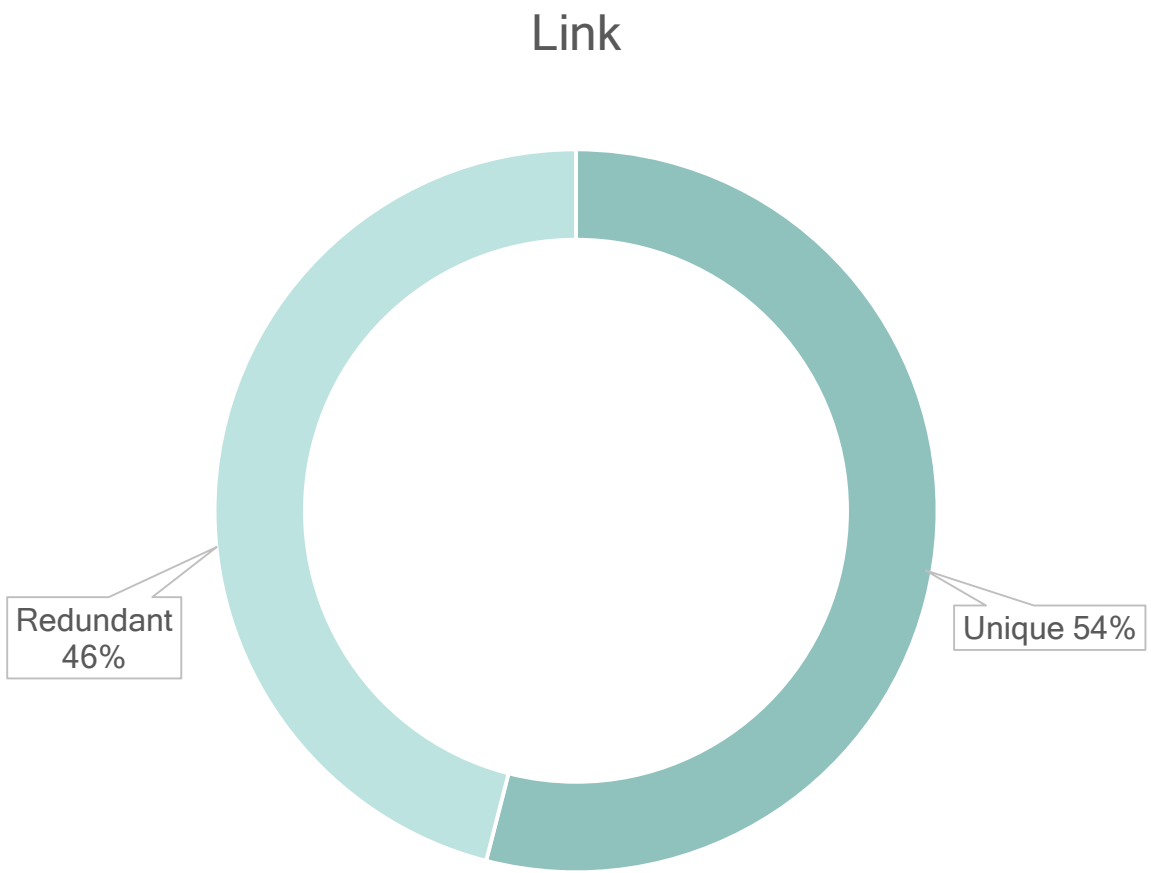

Compile and Link Redundancy

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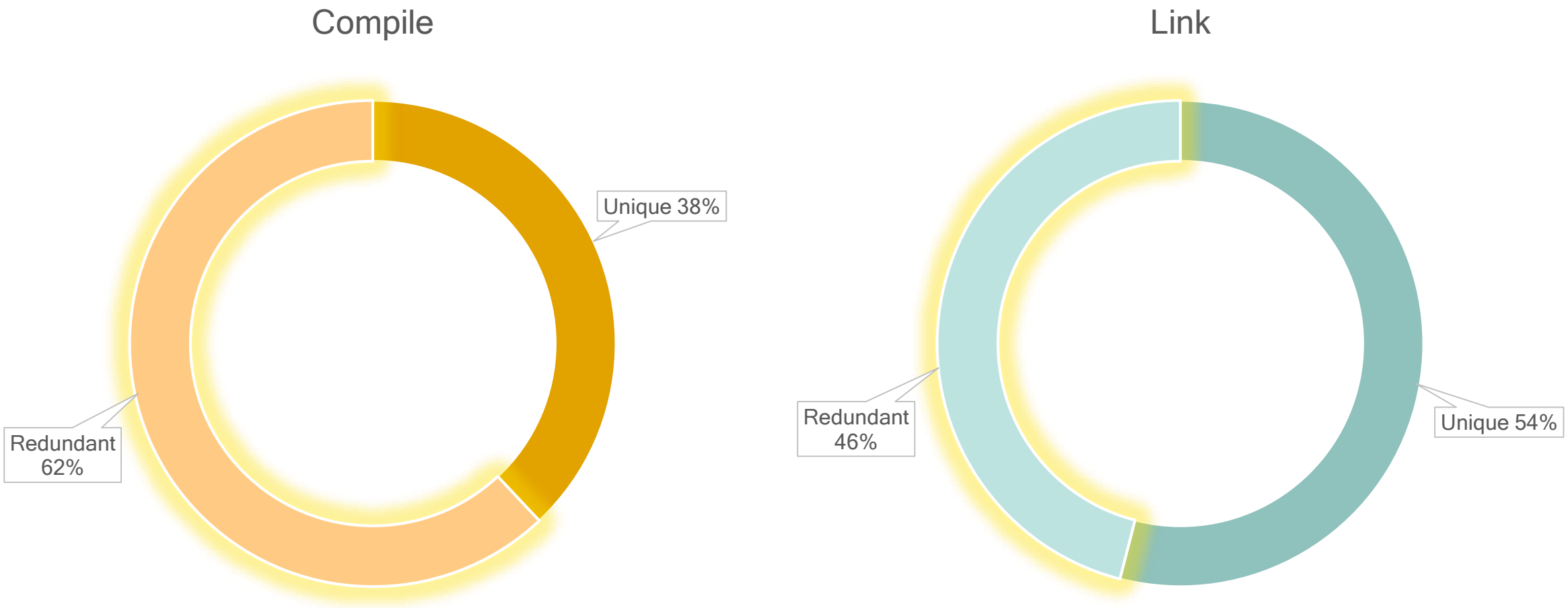

Possible Solutions?

- Reduce number of Pipeline State Objects

“We can’t do much of that.

Maybe if there was more dynamic state?

Maybe if pipeline stages didn’t have to be linked together?”

Possible Solutions?

- Group together similar Pipeline State Objects

“That helps some.

But we have many many many different shaders, so it is hard to group similar pipeline state objects together.”

Possible Solutions?

- Cache prior Pipeline State Objects

“That might work. Tell me more.”

Pipeline Cache

1

Creating a Pipeline State Object without a Pipeline Cache

2

Creating a Pipeline State Object WITH a Pipeline Cache

3

Storing and Loading a Pipeline Cache

Pipeline Cache

1 Creating a Pipeline State Object without a Pipeline Cache

2 Creating a Pipeline State Object WITH a Pipeline Cache

3 Storing and Loading a Pipeline Cache

Creating a Graphics Pipeline

Without Pipeline Cache

```
VkResult result;

VkGraphicsPipelineCreateInfo graphicsPipelineCreateInfo = {};

graphicsPipelineCreateInfo.sType = VK_STRUCTURE_TYPE_GRAPHICS_PIPELINE_CREATE_INFO;
// (set up any additional create info...)

VkPipeline pipeline;

result = vkCreateGraphicsPipelines(
    device,                          // VkDevice                                 device
    VK_NULL_HANDLE,                  // VkPipelineCache                          pipelineCache
    1,                               // uint32_t                                 createInfoCount
    &graphicsPipelineCreateInfo,     // const VkGraphicsPipelineCreateInfo*      pCreateInfos
    nullptr,                         // const VkAllocationCallbacks*             pAllocator
    &pipeline);                      // VkPipeline*                              pPipelines
```

Creating a Graphics Pipeline

Without Pipeline Cache

```
VkResult result;

VkGraphicsPipelineCreateInfo graphicsPipelineCreateInfo = {};

graphicsPipelineCreateInfo.sType = VK_STRUCTURE_TYPE_GRAPHICS_PIPELINE_CREATE_INFO;
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    &graphicsPipelineCreateInfo,     // const VkGraphicsPipelineCreateInfo*      pCreateInfos
    nullptr,                         // const VkAllocationCallbacks*             pAllocator
    &pipeline);                      // VkPipeline*                              pPipelines
```

Pipeline State Objects Create Time Percentage

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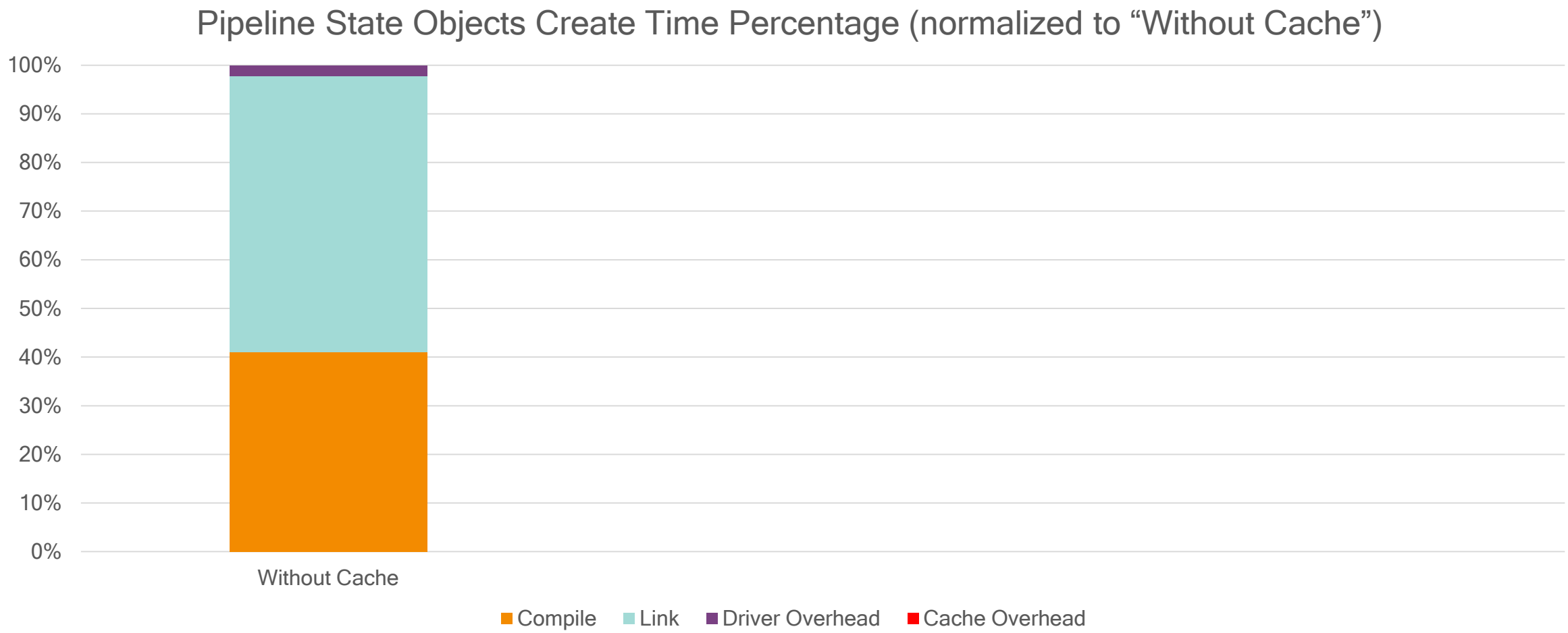


Pipeline Cache

1

Creating a Pipeline State Object without a Pipeline Cache

2

Creating a Pipeline State Object WITH a Pipeline Cache

3

Storing and Loading a Pipeline Cache

Creating a Pipeline Cache

```
VkResult result;

static VkPipelineCache pipelineCache;
VkPipelineCacheCreateInfo pipelineCacheCreateInfo = {};

pipelineCacheCreateInfo.sType = VK_STRUCTURE_TYPE_PIPELINE_CACHE_CREATE_INFO;
// (set up any additional create info...)


result = vkCreatePipelineCache(
    device,                                 // VkDevice                                 device,
    &pipelineCacheCreateInfo,               // const VkPipelineCacheCreateInfo*         pCreateInfo,
    nullptr,                                // const VkAllocationCallbacks*             pAllocator,
    &pipelineCache);                        // VkPipelineCache*                         pPipelineCache);

// continued...
```

Creating a Pipeline Cache

```
VkResult result;

static VkPipelineCache pipelineCache;
VkPipelineCacheCreateInfo pipelineCacheCreateInfo = {};

pipelineCacheCreateInfo.sType = VK_STRUCTURE_TYPE_PIPELINE_CACHE_CREATE_INFO;
// (set up any additional create info...)


result = vkCreatePipelineCache(
    device,                             // VkDevice                         device,
    &pipelineCacheCreateInfo,           // const VkPipelineCacheCreateInfo* pCreateInfo,
    nullptr,                            // const VkAllocationCallbacks*     pAllocator,
    &pipelineCache);                    // VkPipelineCache*                 pPipelineCache);

// continued...
```

Creating a Graphics Pipeline

WITH Pipeline Cache

```
// ...continued

VkGraphicsPipelineCreateInfo graphicsPipelineCreateInfo = {};

graphicsPipelineCreateInfo.sType = VK_STRUCTURE_TYPE_GRAPHICS_PIPELINE_CREATE_INFO;
// (set up any additional create info...)

VkPipeline pipeline;

result = vkCreateGraphicsPipelines(
    device,                         // VkDevice                                 device
    pipelineCache,                  // VkPipelineCache                          pipelineCache
    1,                              // uint32_t                                 createInfoCount
    &graphicsPipelineCreateInfo,    // const VkGraphicsPipelineCreateInfo*      pCreateInfos
    nullptr,                        // const VkAllocationCallbacks*             pAllocator
    &pipeline);                     // VkPipeline*                              pPipelines
```

Creating a Graphics Pipeline

WITH Pipeline Cache

```
// ...continued

VkGraphicsPipelineCreateInfo graphicsPipelineCreateInfo = {};

graphicsPipelineCreateInfo.sType = VK_STRUCTURE_TYPE_GRAPHICS_PIPELINE_CREATE_INFO;
// (set up any additional create info...)

VkPipeline pipeline;

result = vkCreateGraphicsPipelines(
    device,                          // VkDevice                                 device
    pipelineCache,                   // VkPipelineCache                          pipelineCache
    1,                               // uint32_t                                 createInfoCount
    &graphicsPipelineCreateInfo,     // const VkGraphicsPipelineCreateInfo*      pCreateInfos
    nullptr,                         // const VkAllocationCallbacks*             pAllocator
    &pipeline);                      // VkPipeline*                              pPipelines
```

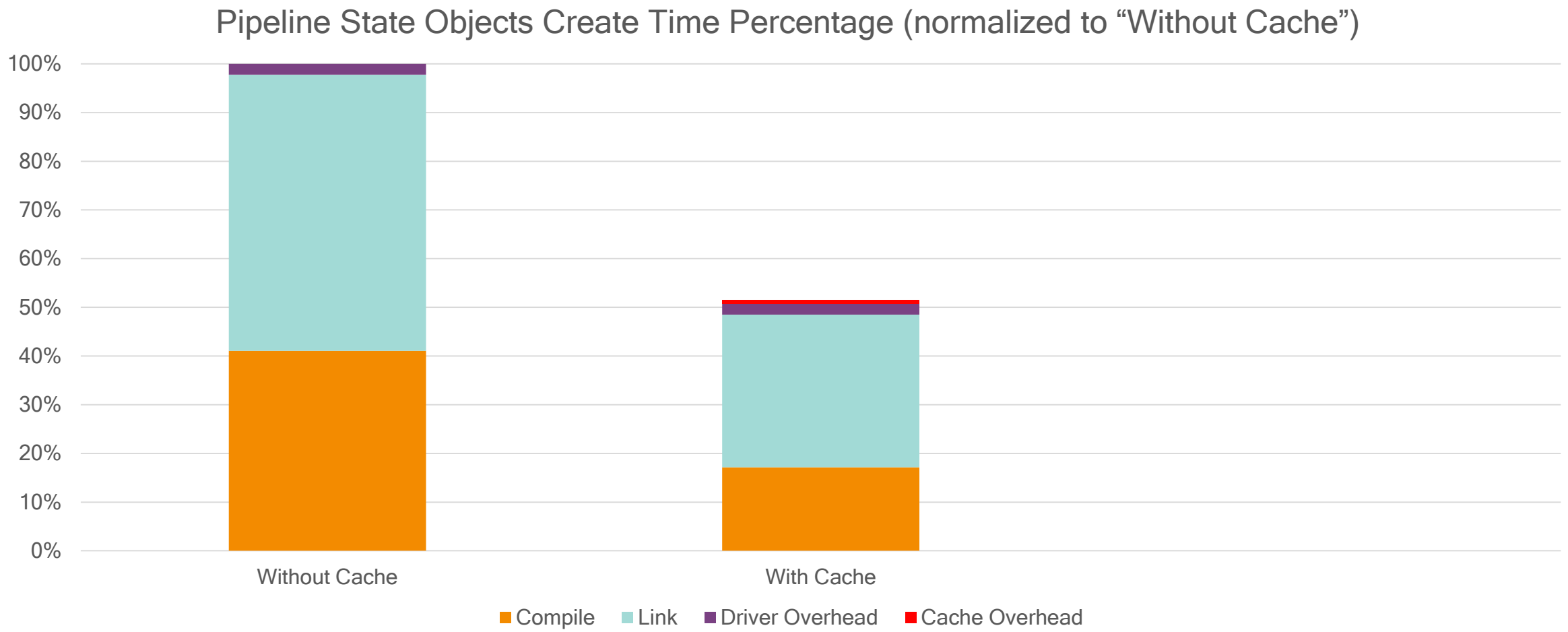
Creating a Graphics Pipeline

WITH Pipeline Cache

```
// ...continued

VkGraphicsPipelineCreateInfo graphicsPipelineCreateInfo = {};

graphicsPipelineCreateInfo.sType = VK_STRUCTURE_TYPE_GRAPHICS_PIPELINE_CREATE_INFO;
// (set up any additional create info...)

VkPipeline pipeline;

result = vkCreateGraphicsPipelines(
    device,                         // VkDevice                                 device
    pipelineCache,                  // VkPipelineCache                          pipelineCache
    1,                              // uint32_t                                 createInfoCount
    &graphicsPipelineCreateInfo,    // const VkGraphicsPipelineCreateInfo*      pCreateInfos
    nullptr,                        // const VkAllocationCallbacks*             pAllocator
    &pipeline);                     // VkPipeline*                              pPipelines
```

Pipeline State Objects Create Time Percentage

Epic Games ProtoStar



Pipeline Cache

1 Creating a Pipeline State Object without a Pipeline Cache

2 Creating a Pipeline State Object WITH a Pipeline Cache

3 Storing and Loading a Pipeline Cache

Get Pipeline Cache Data

```
VkResult result;

size_t pipelineCacheSize;
unsigned char pipelineCacheData[MAX_PIPELINE_CACHE_STORE];

result = vkGetPipelineCacheData(
    device,                             // VkDevice                         device
    pipelineCache,                      // VkPipelineCache                  pipelineCache
    &pipelineCacheSize,                 // size_t*                          pDataSize
    nullptr);                           // void*                            pData

pipelineCacheSize = min(pipelineCacheSize,MAX_PIPELINE_CACHE_STORE);

result = vkGetPipelineCacheData(
    device,                             // VkDevice                         device
    pipelineCache,                      // VkPipelineCache                  pipelineCache
    &pipelineCacheSize,                 // size_t*                          pDataSize
    &pipelineCacheData[0]);             // void*                            pData

int storeResult = storeToStorage(pipelinecacheSize, &pipelineCacheData[0]);
```

Create Pipeline Cache

WITH initial data

```
VkResult result;

static VkPipelineCache pipelineCache;
VkPipelineCacheCreateInfo pipelineCacheCreateInfo = {};

size_t pipelineCacheSize;
unsigned char pipelineCacheData[MAX_PIPELINE_CACHE_STORE];

int loadResult = loadFromStorage(MAX_PIPELINE_CACHE_STORE, &pipelineCacheSize, &pipelineCacheData[0]);

pipelineCacheCreateInfo.sType = VK_STRUCTURE_TYPE_PIPELINE_CACHE_CREATE_INFO;
// (set up any additional create info...)
pipelineCacheCreateInfo.initialDataSize = pipelineCacheSize;
pipelineCacheCreateInfo.pInitialData = &pipelineCacheData[0];

result = vkCreatePipelineCache(
    device,                             // VkDevice                             device,
    &pipelineCacheCreateInfo,           // const VkPipelineCacheCreateInfo*     pCreateInfo,
    nullptr,                            // const VkAllocationCallbacks*         pAllocator,
    &pipelineCache);                    // VkPipelineCache*                     pPipelineCache);
```

Create Pipeline Cache

WITH initial data

```
VkResult result;

static VkPipelineCache pipelineCache;
VkPipelineCacheCreateInfo pipelineCacheCreateInfo = {};

size_t pipelineCacheSize;
unsigned char pipelineCacheData[MAX_PIPELINE_CACHE_STORE];

int loadResult = loadFromStorage(MAX_PIPELINE_CACHE_STORE, &pipelineCacheSize, &pipelineCacheData[0]);

pipelineCacheCreateInfo.sType = VK_STRUCTURE_TYPE_PIPELINE_CACHE_CREATE_INFO;
// (set up any additional create info...)
pipelineCacheCreateInfo.initialDataSize = pipelineCacheSize;
pipelineCacheCreateInfo.pInitialData = &pipelineCacheData[0];

result = vkCreatePipelineCache(
    device,                         // VkDevice                         device,
    &pipelineCacheCreateInfo,       // const VkPipelineCacheCreateInfo* pCreateInfo,
    nullptr,                        // const VkAllocationCallbacks*     pAllocator,
    &pipelineCache);                // VkPipelineCache*                 pPipelineCache);
```

Pipeline State Objects Create Time

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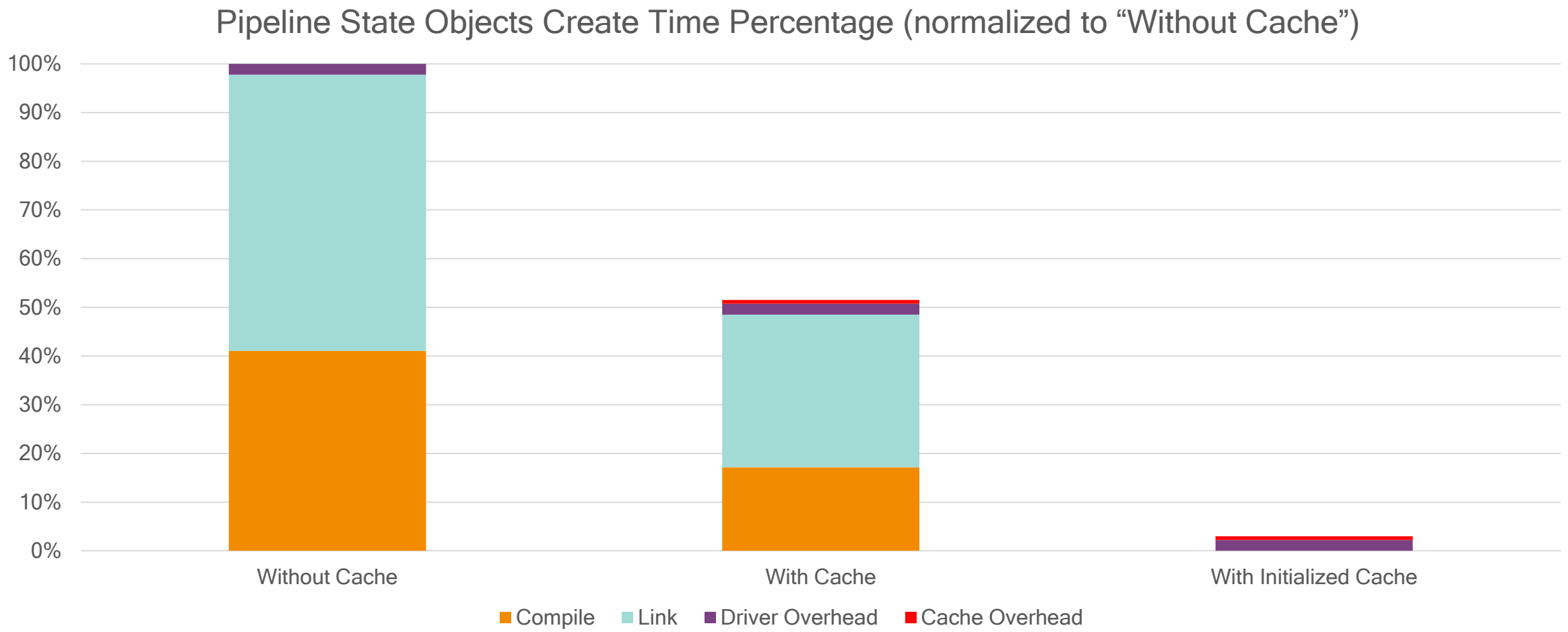

Pipeline Cache Object is internally synchronized

Applications MAY access a pipeline cache from multiple threads without external synchronization

BUT - Host access to Pipeline Cache object MUST be externally synchronized

Pipeline Cache Header

Offset	Size	Description
0	4	length in bytes of the entire pipeline cache header written as a stream of bytes, with the least significant byte first
4	4	a VkPipelineCacheHeaderVersion value written as a stream of bytes, with the least significant byte first
8	4	a vendor ID equal to VkPhysicalDeviceProperties::vendorID written as a stream of bytes, with the least significant byte first
12	4	a device ID equal to VkPhysicalDeviceProperties::deviceID written as a stream of bytes, with the least significant byte first
16	VK_UUID_SIZE	a pipeline cache ID equal to VkPhysicalDeviceProperties::pipelineCacheUUID

Summary

- Using a pipeline cache is easy
- Using a pipeline cache reduces redundant compiles and links
- Saving and loading a pipeline cache may reduce compile and link to first application use
  - Local storage on device required
  - Cache may be invalidated by OS updates and/or Driver updates
- Storing a cache in the cloud is an option
  - Wi-Fi or Cellular Data required

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Acknowledgements

Dan Archard
Engineer, Principal
ACG
Qualcomm Technologies, Inc.

Epic Games

Vulkan Working Group

Thank you

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