Advanced Touch Input on iOS

Increasing Responsiveness by Reducing Latency

Session 233

Peter Tsoi iOS Performance Engineer
Jacob Xiao UIKit Engineer

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Overview

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Discuss how to find and fix performance bottlenecks

Why Is Low Latency Important?

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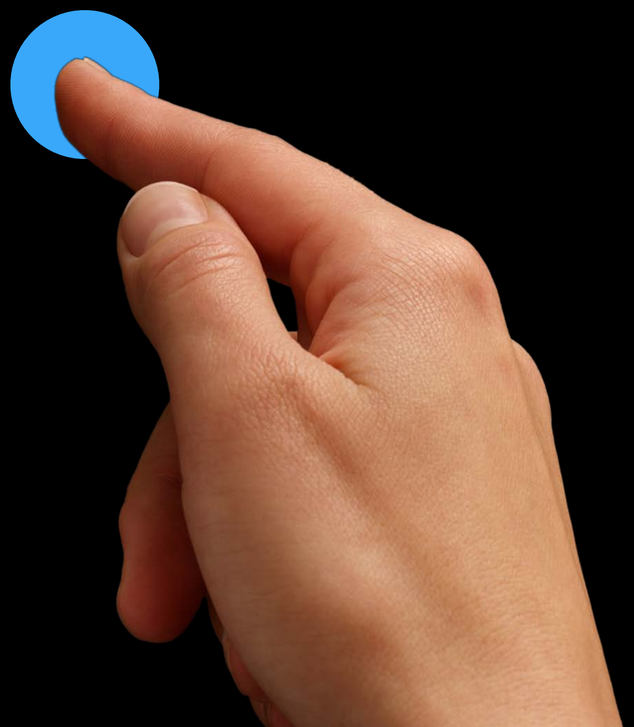

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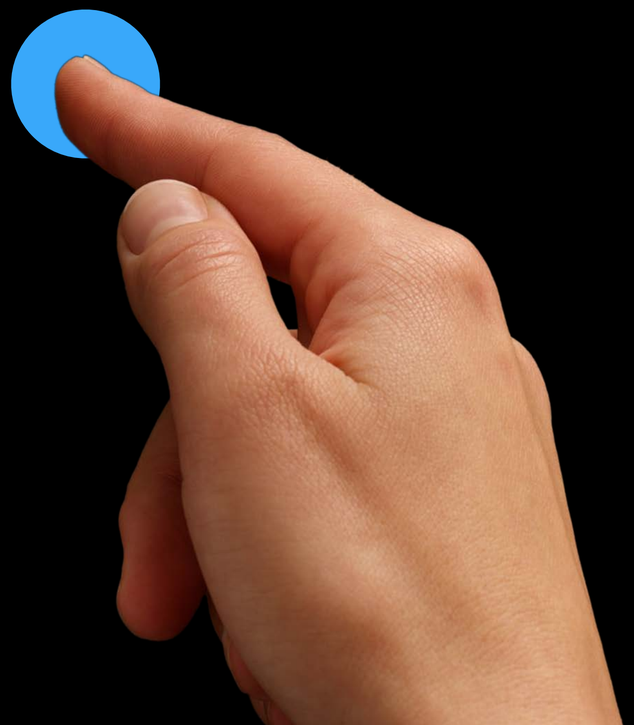

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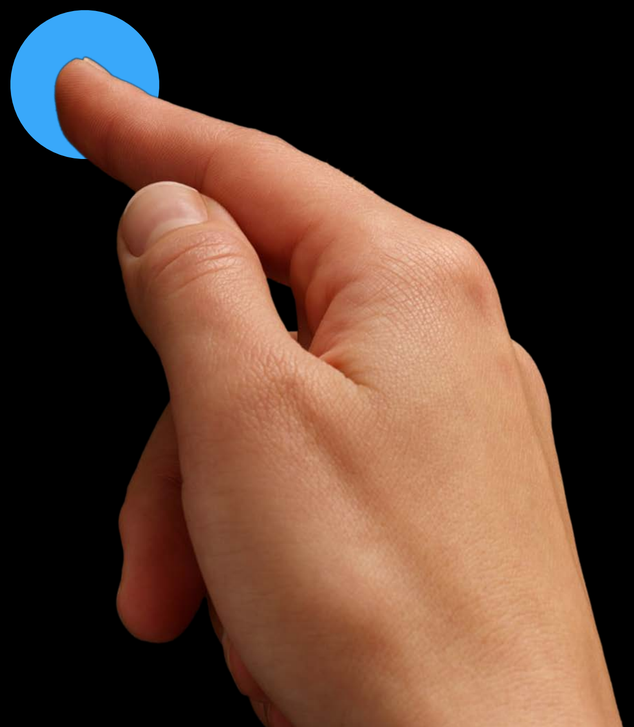

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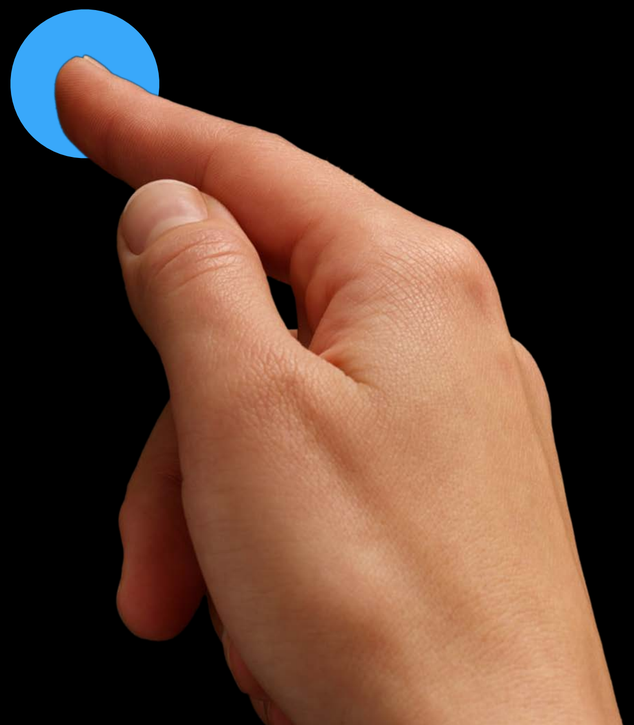

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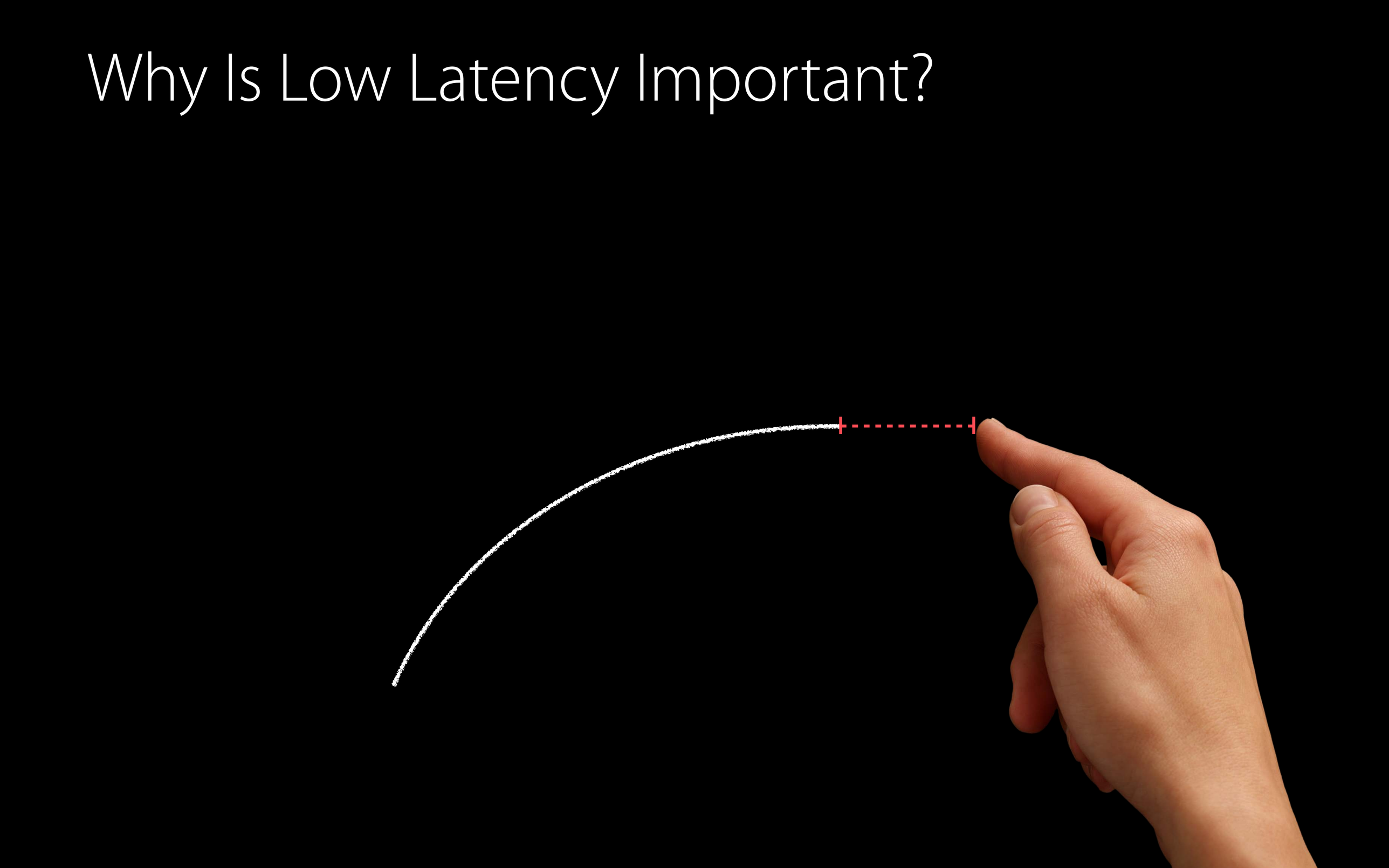

The iOS Touch and Graphics Pipeline

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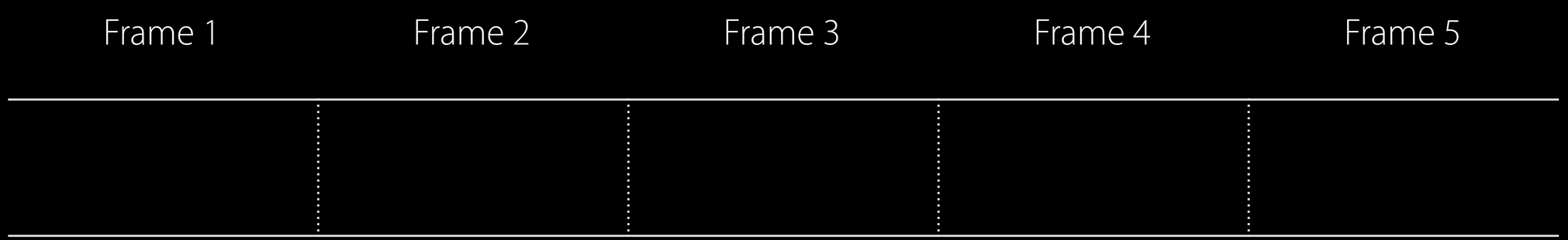

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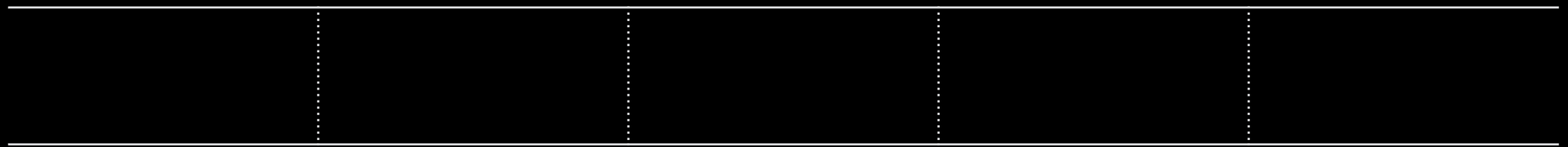

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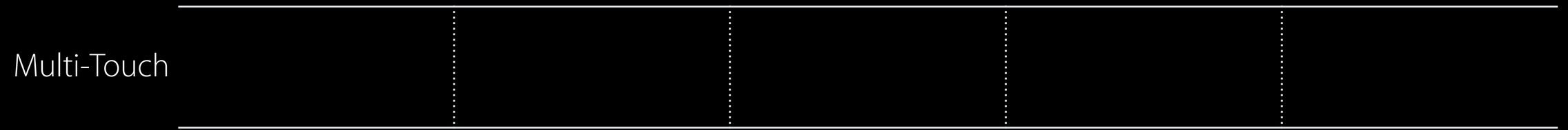

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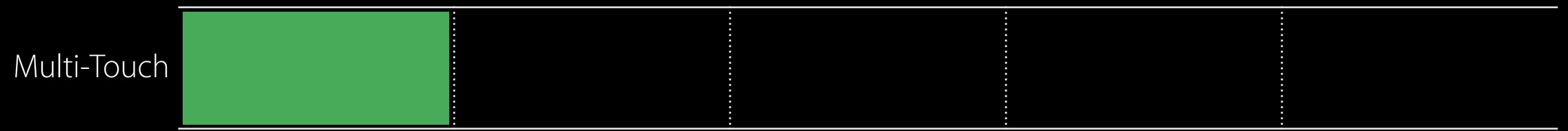

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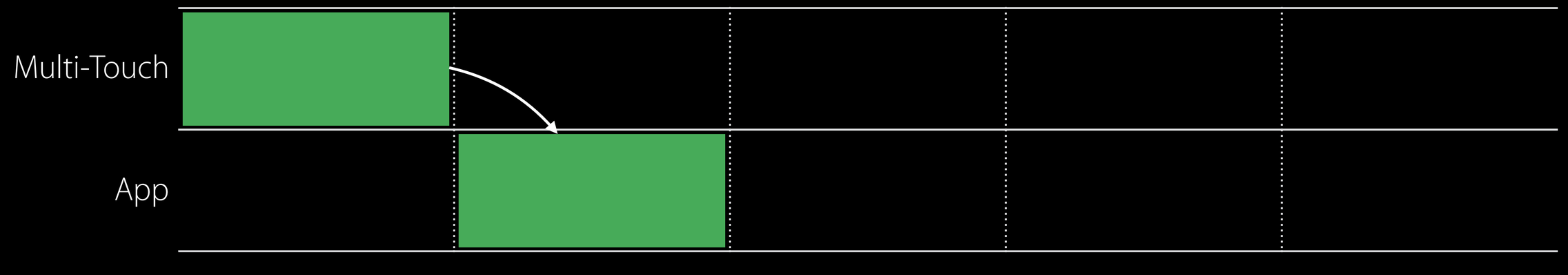

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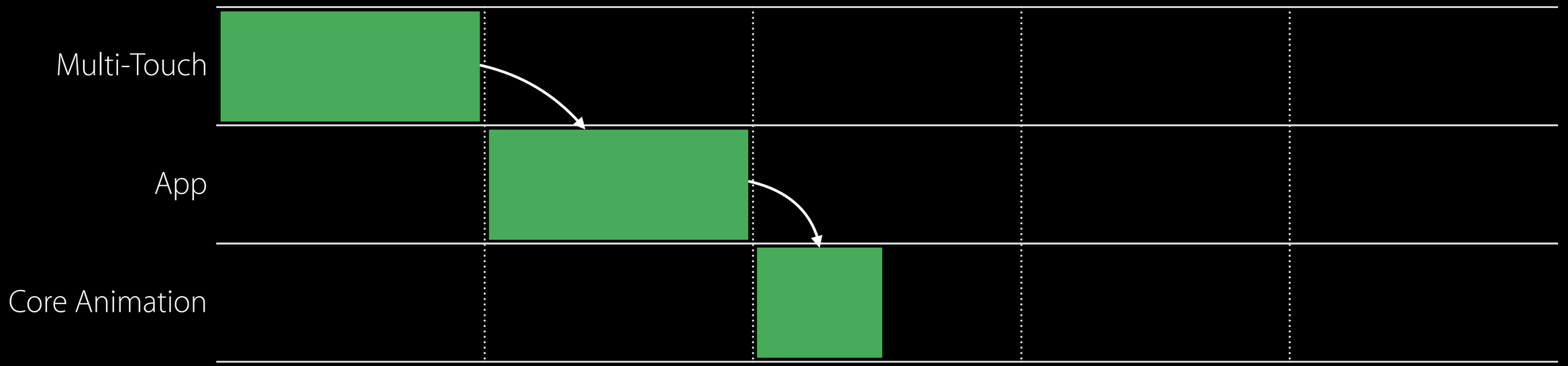

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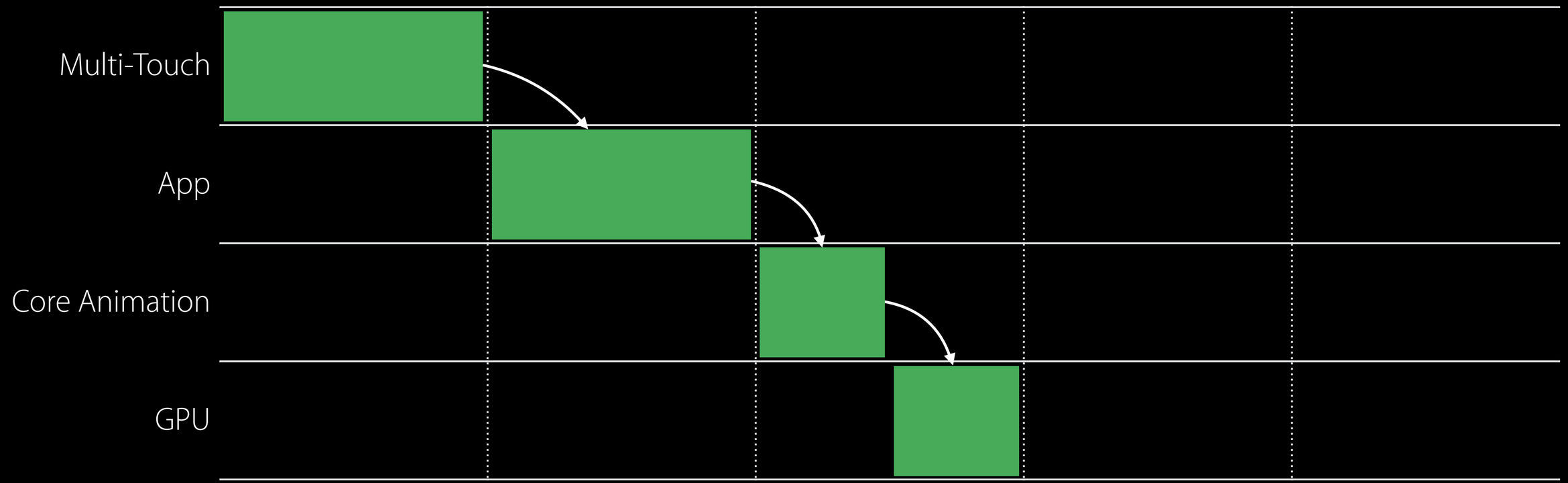

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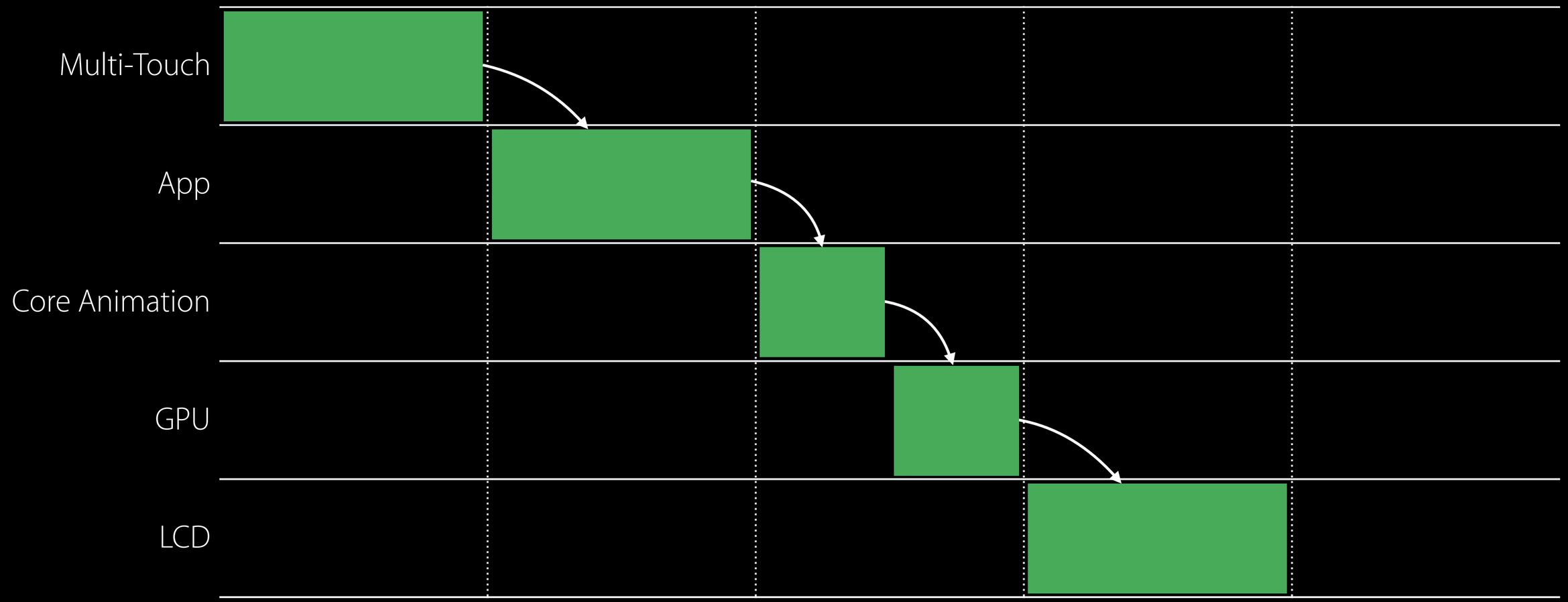

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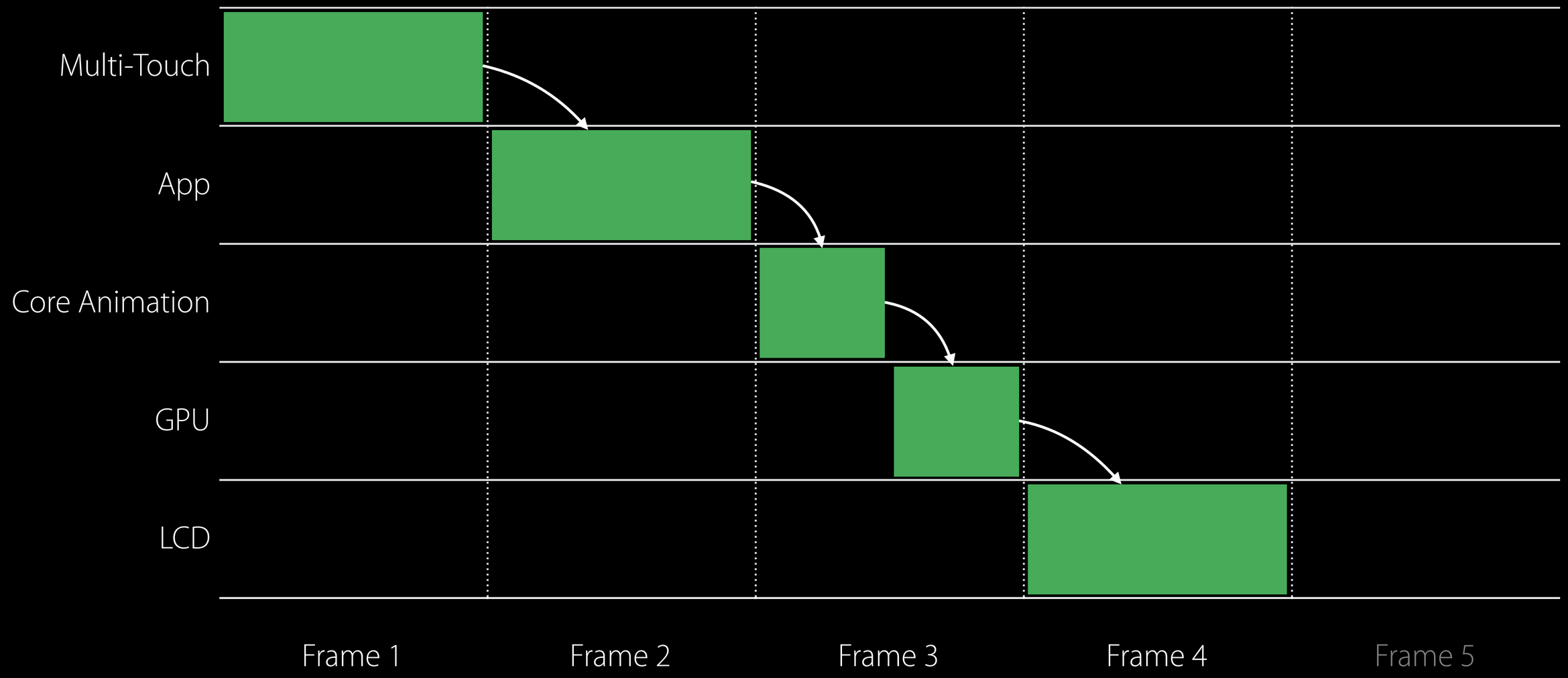

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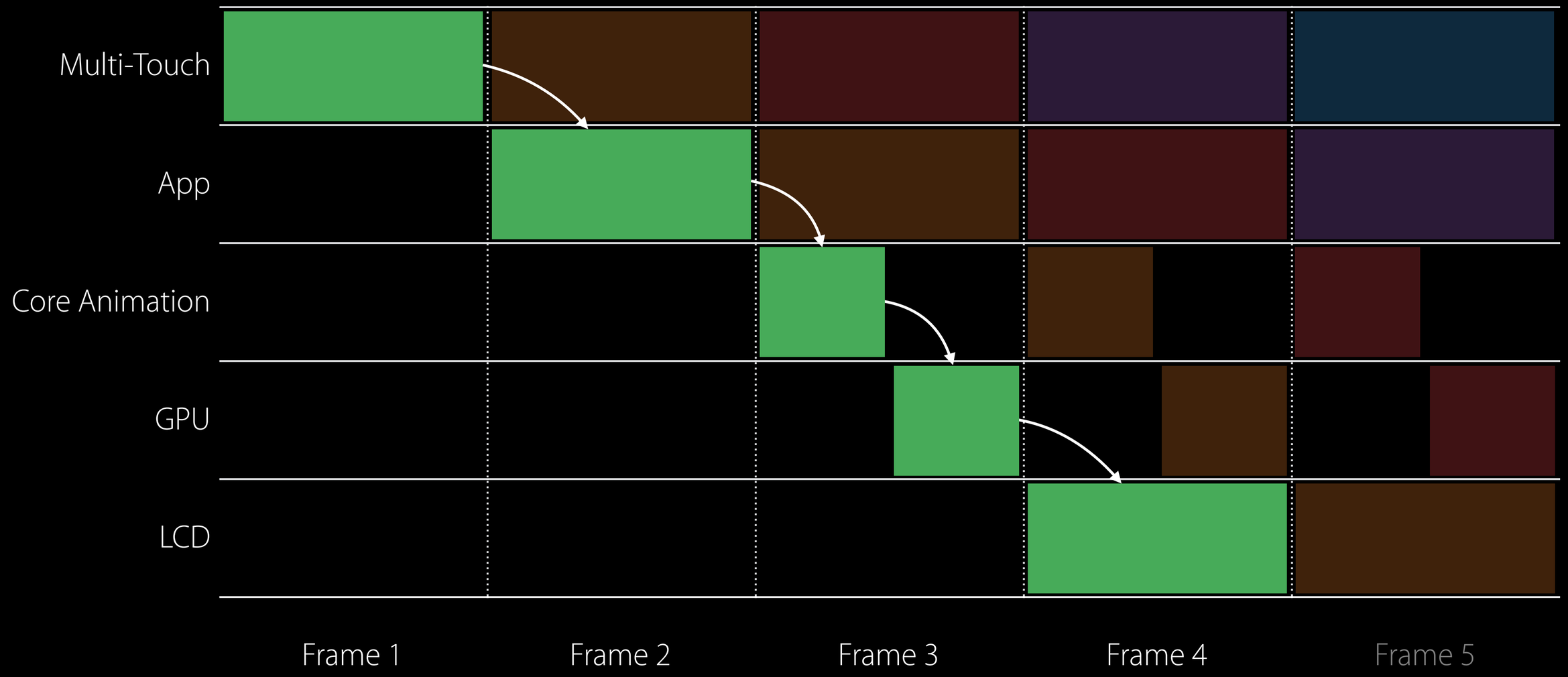

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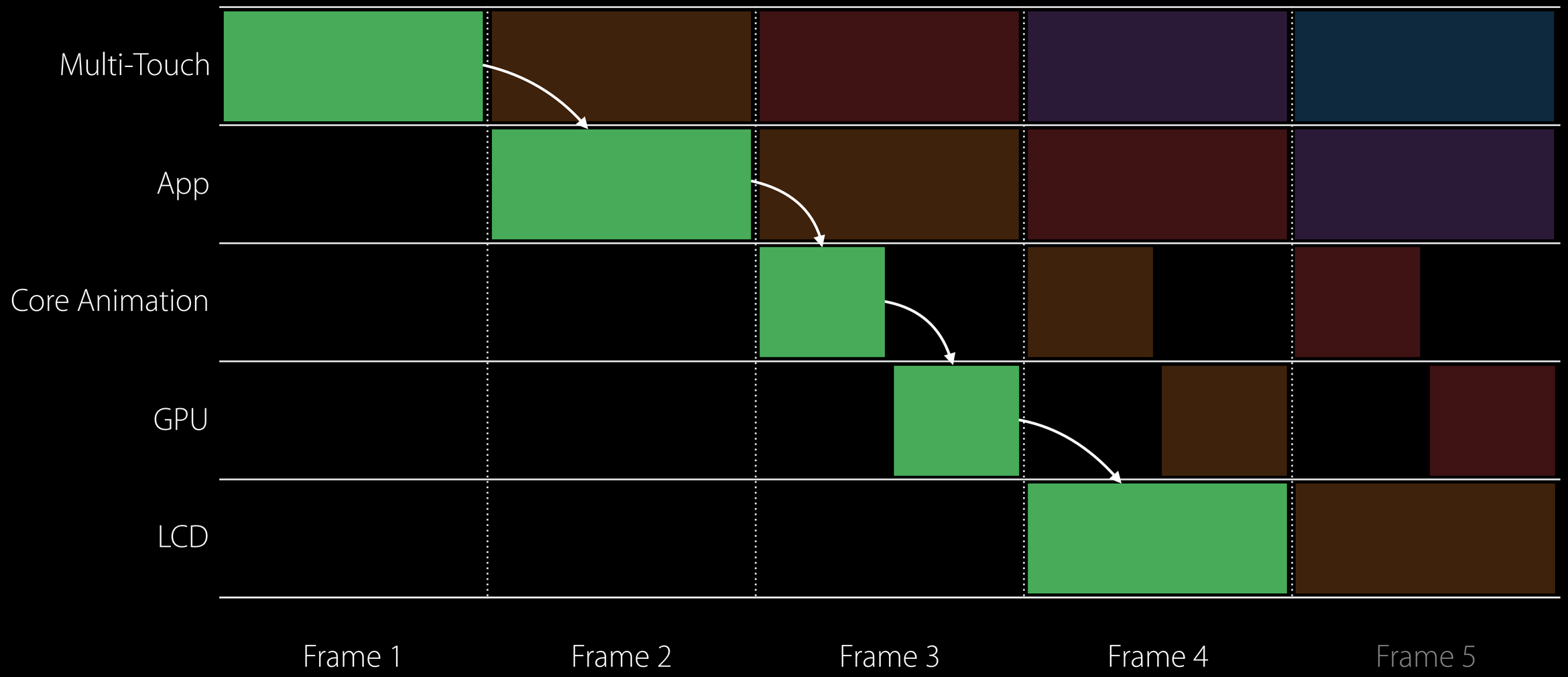

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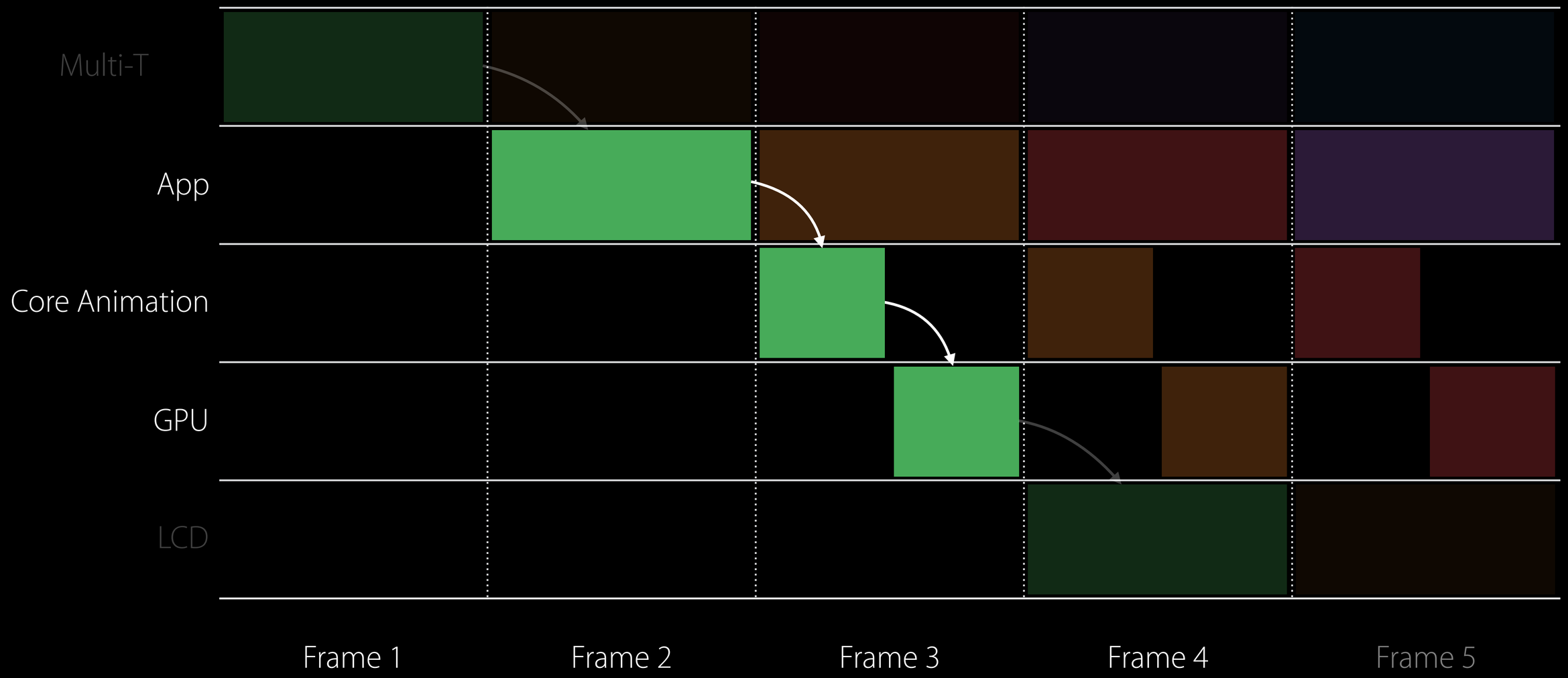

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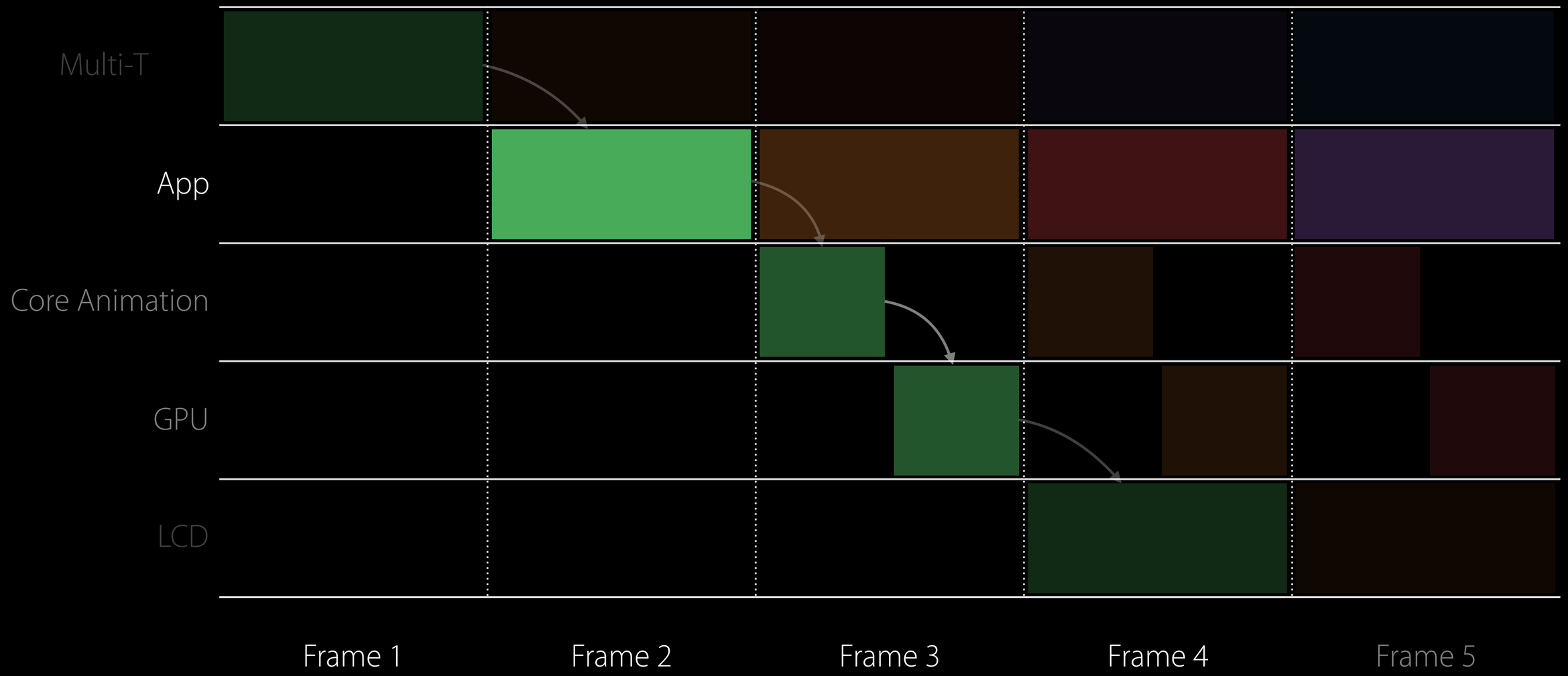

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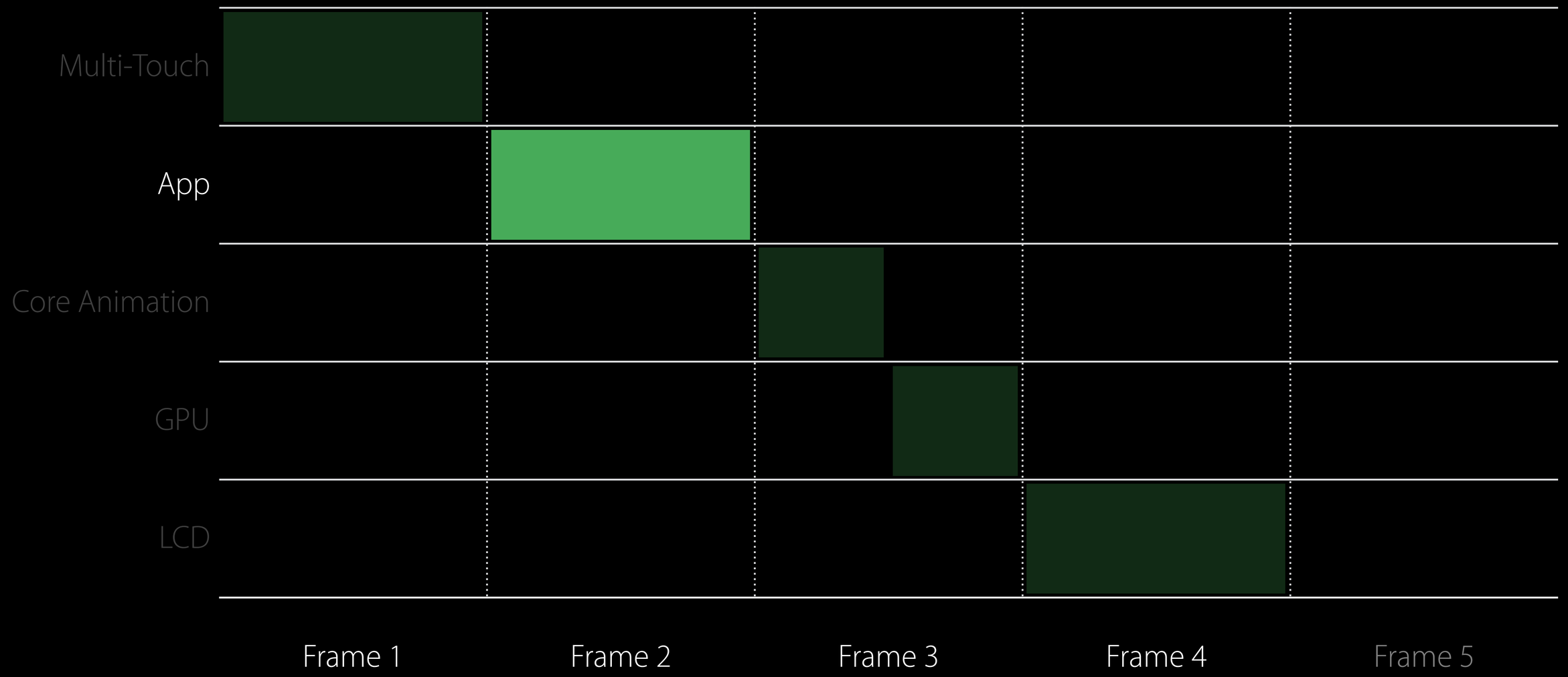

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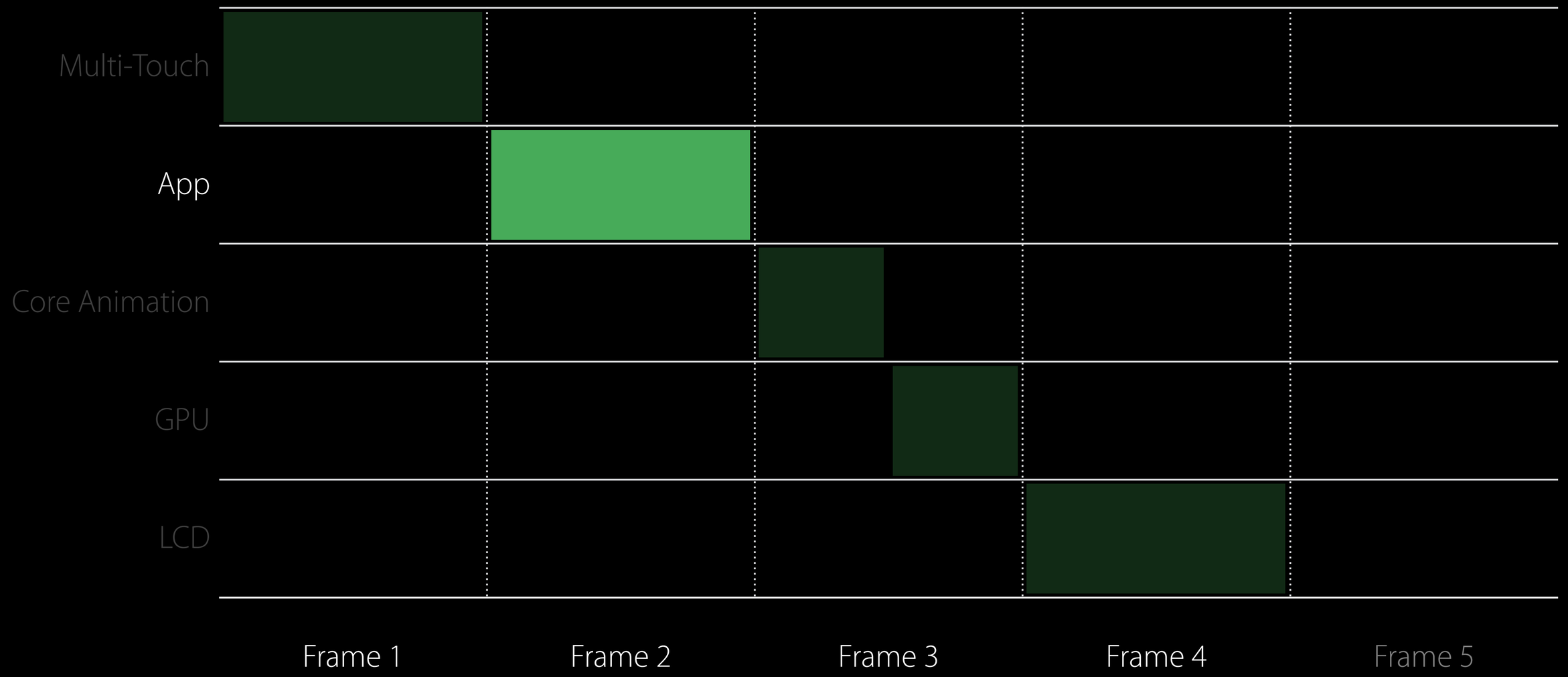

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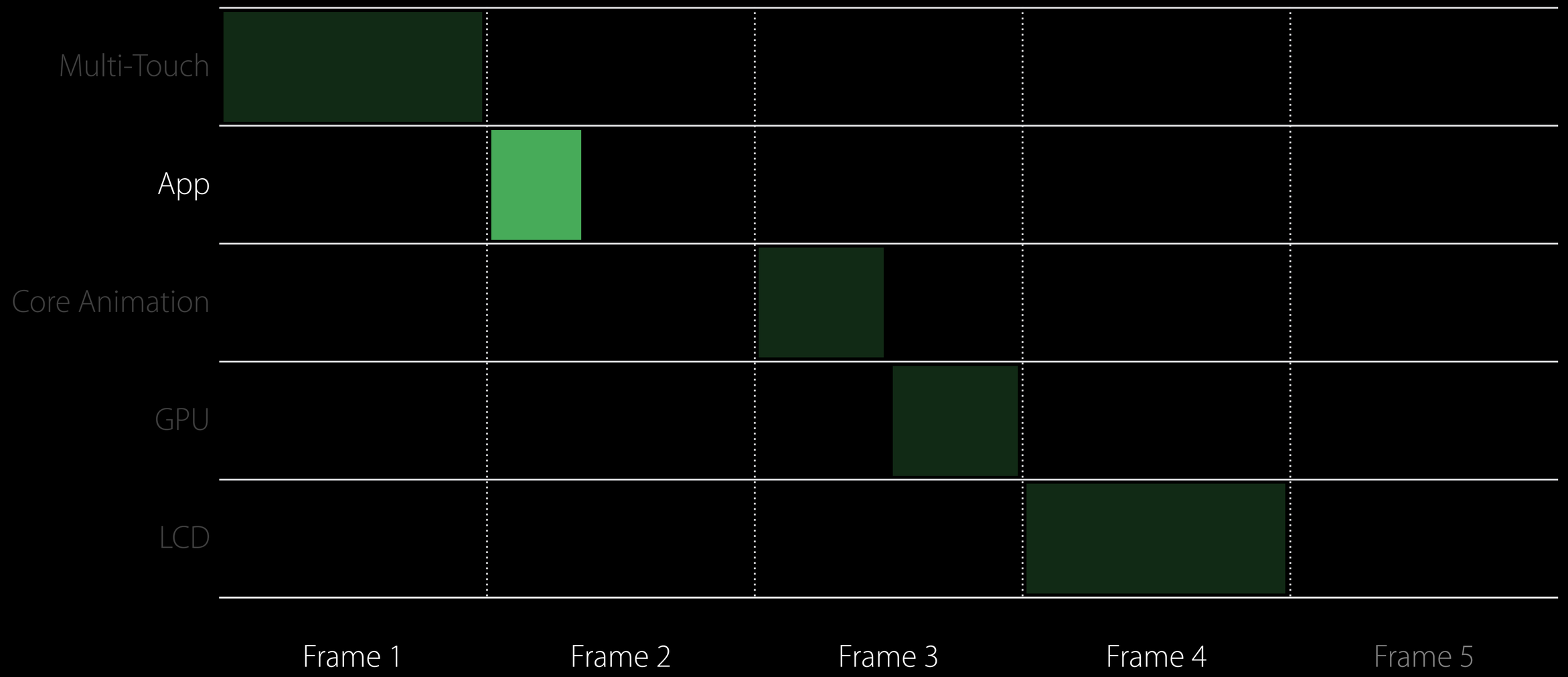

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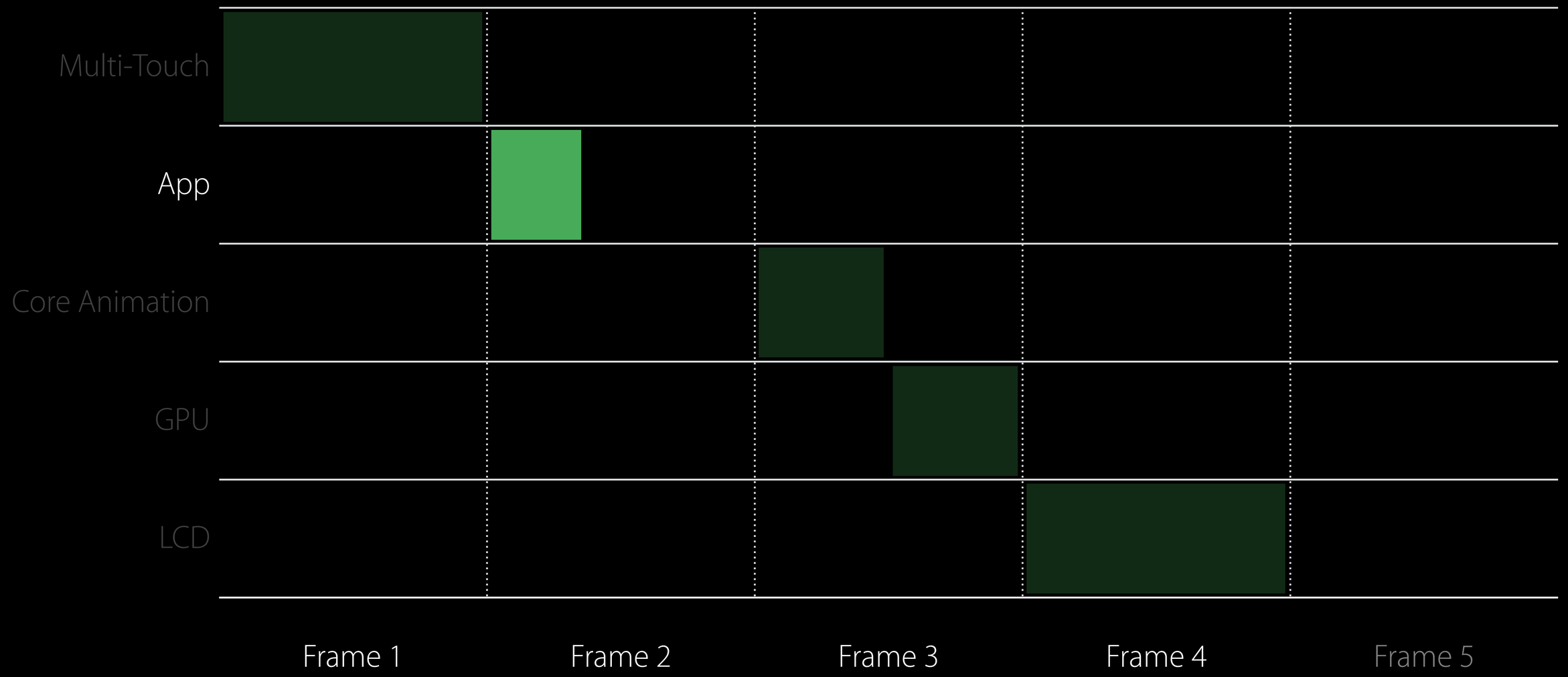

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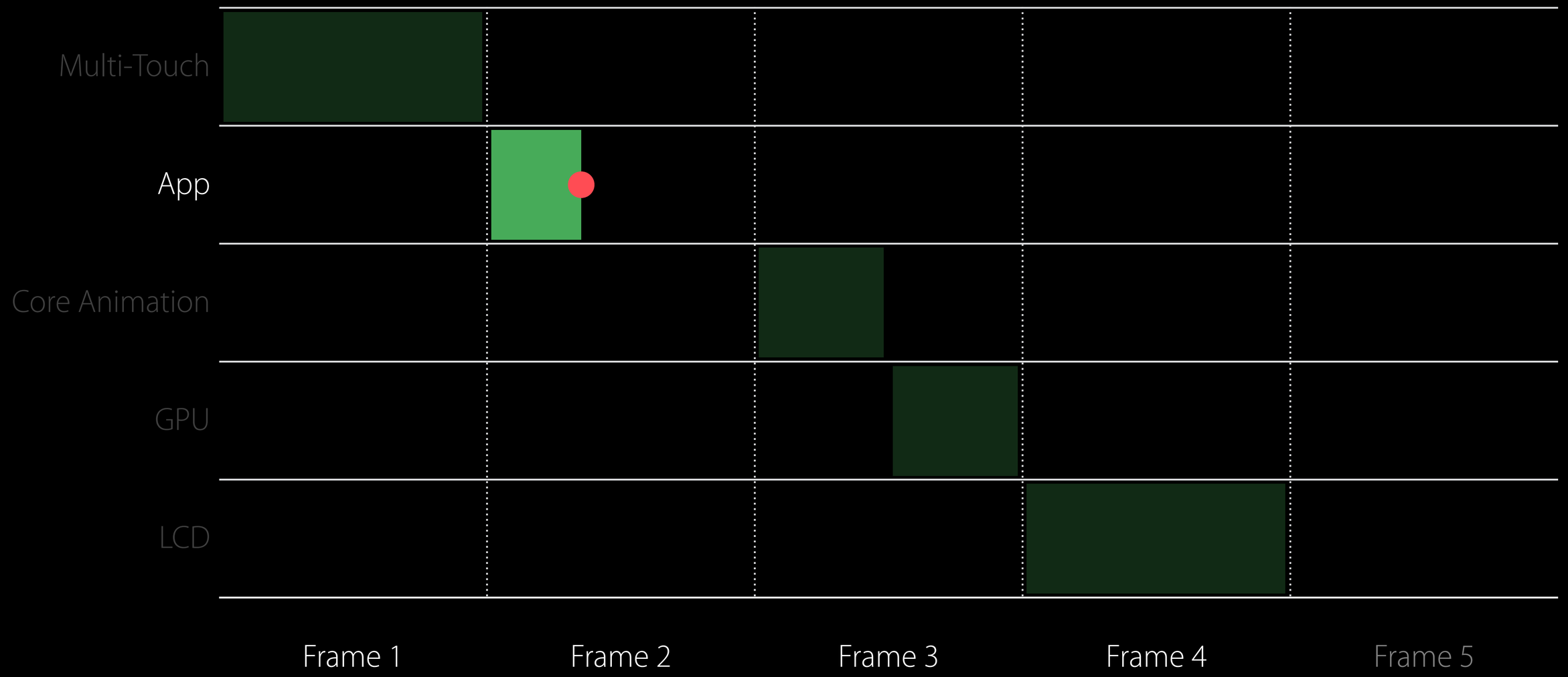

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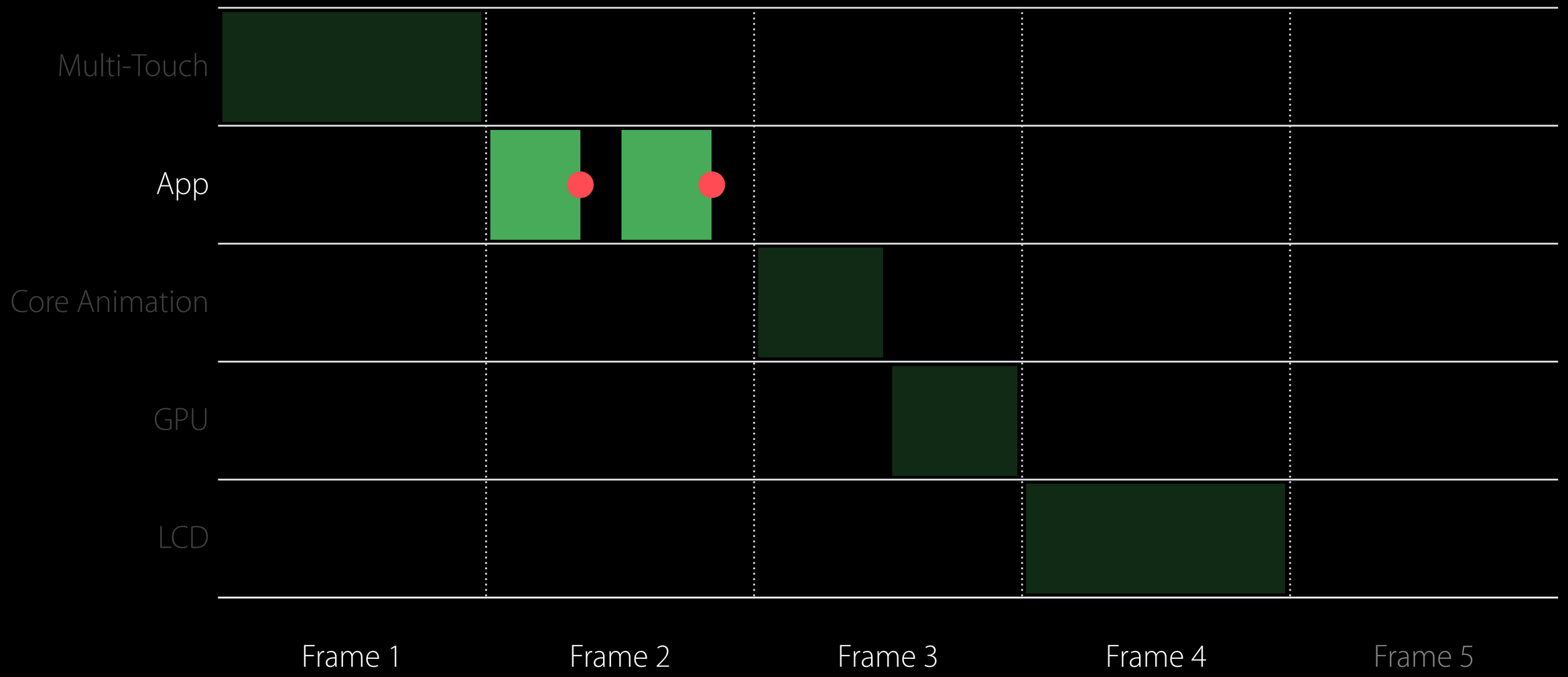

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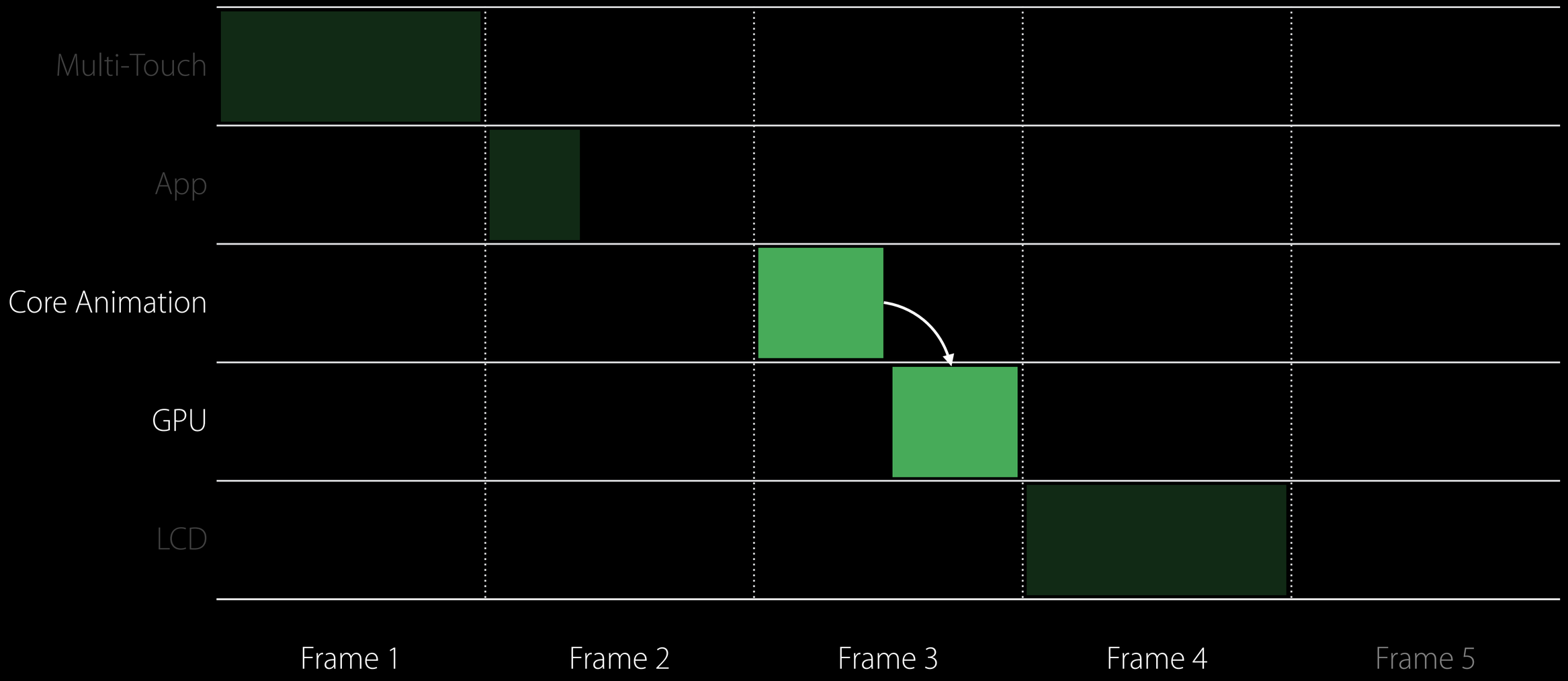

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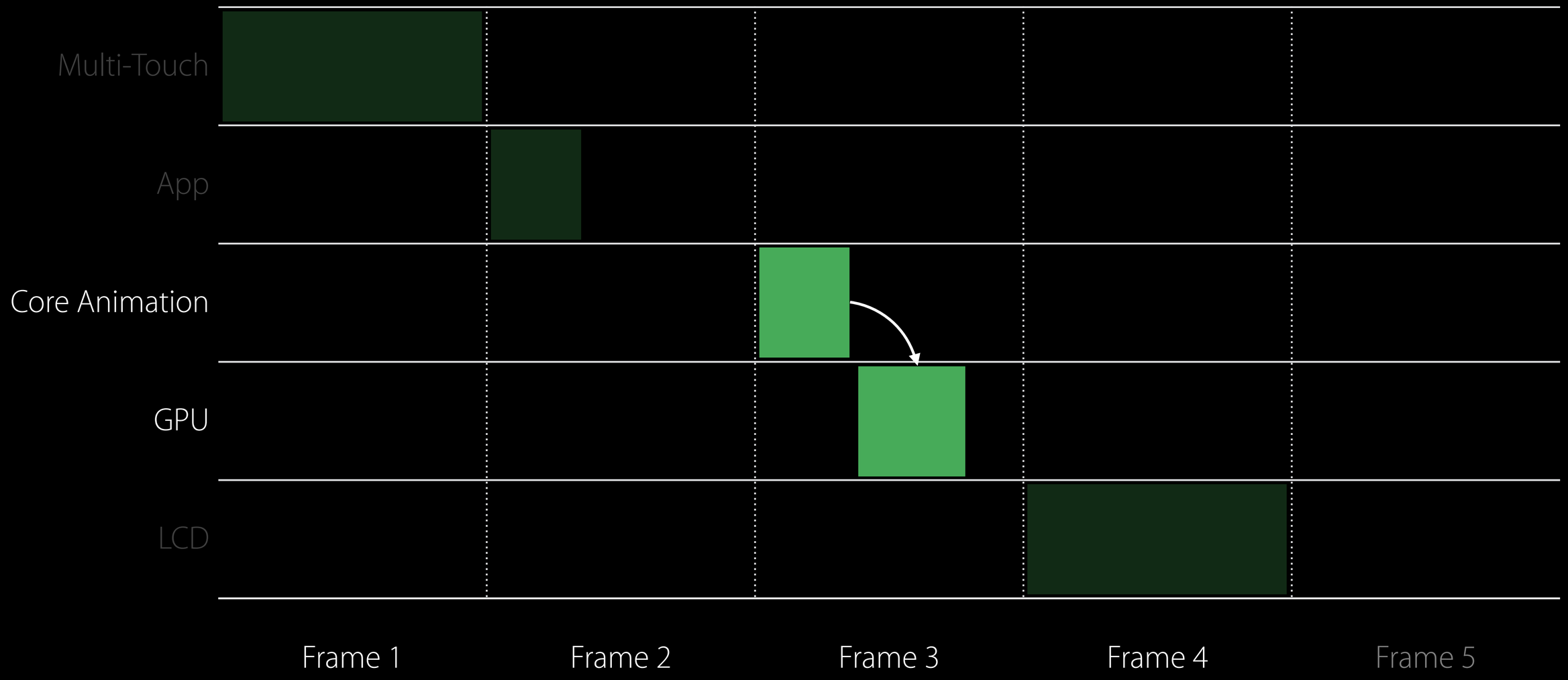

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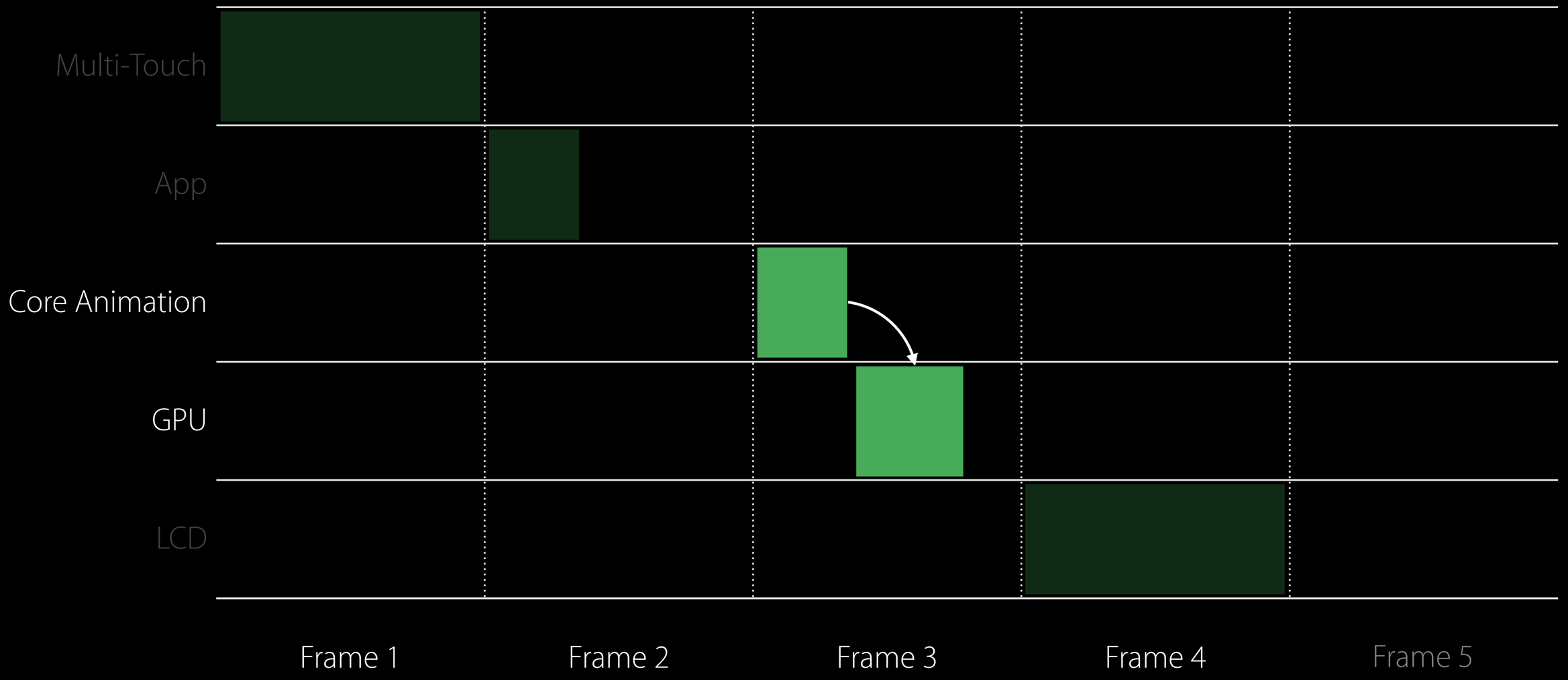

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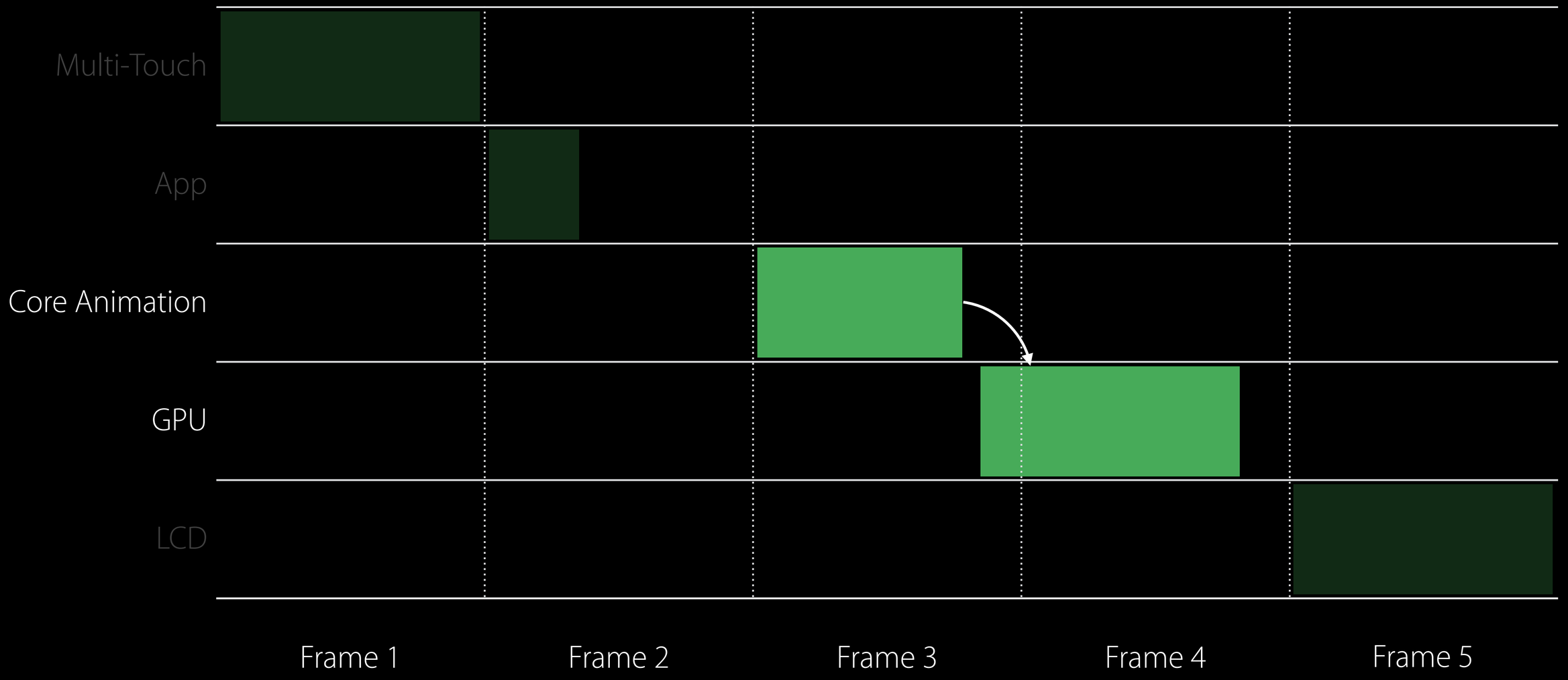

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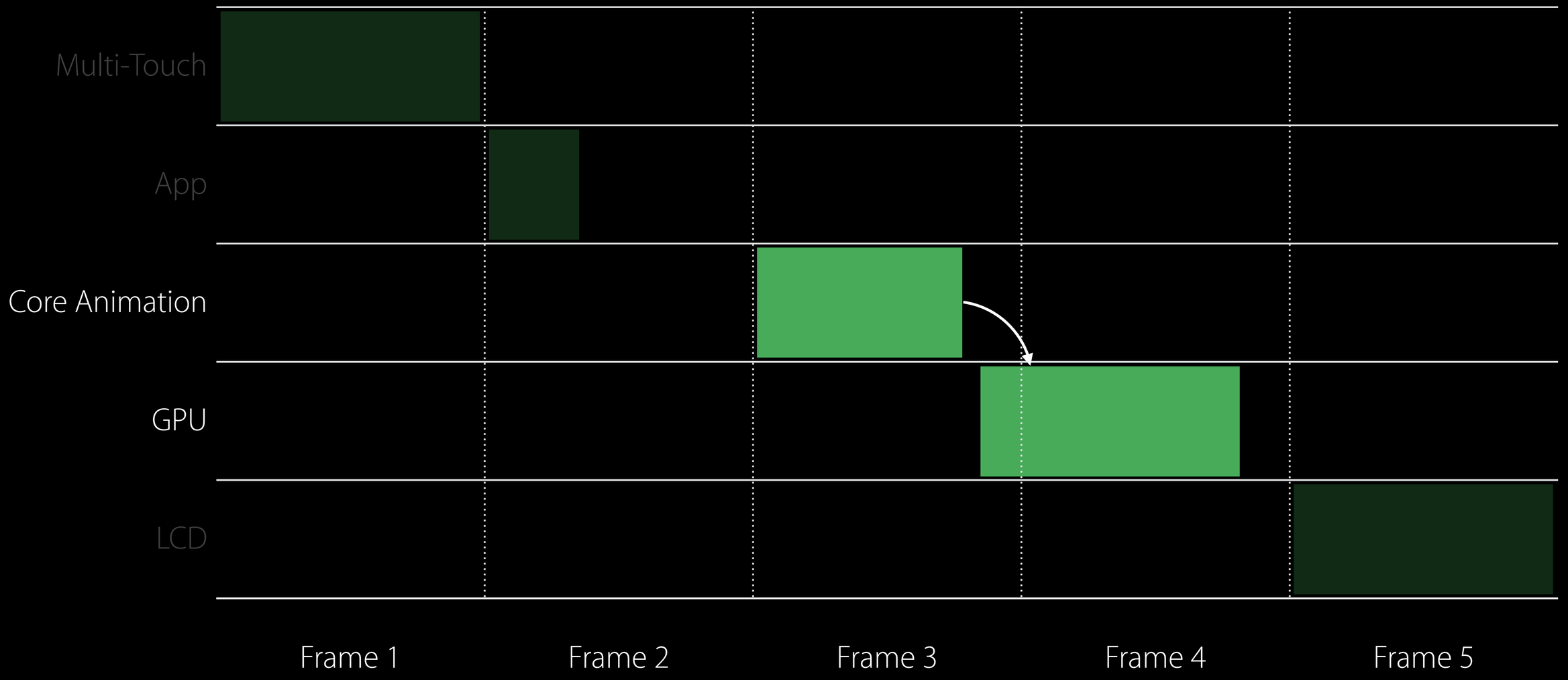

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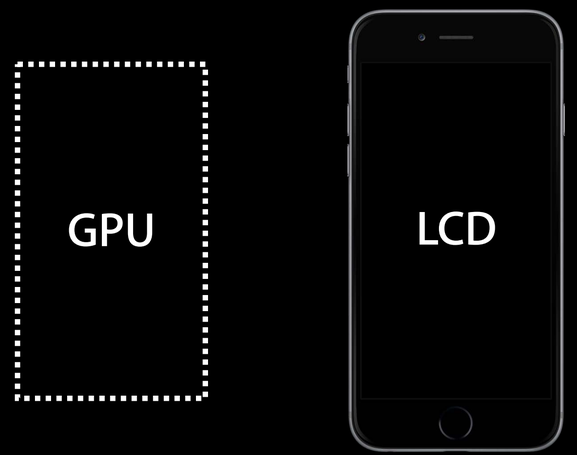

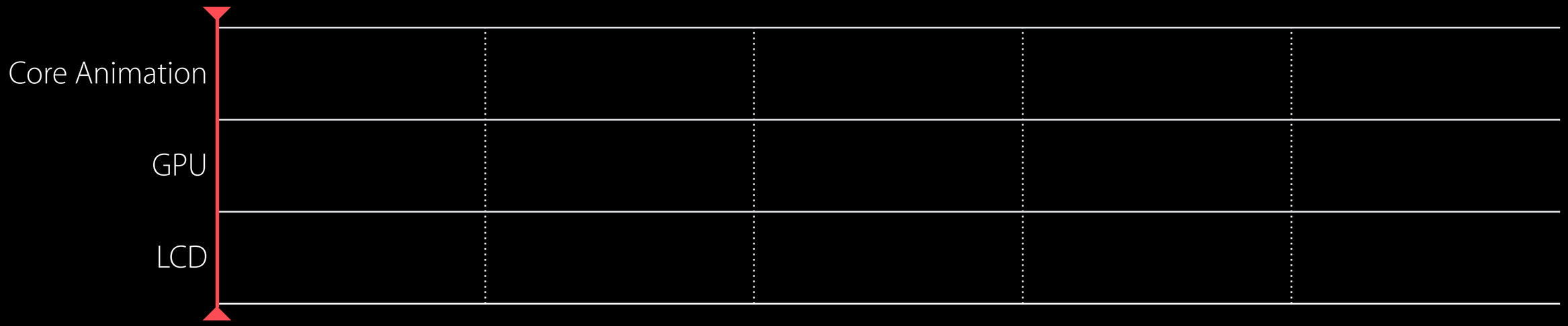

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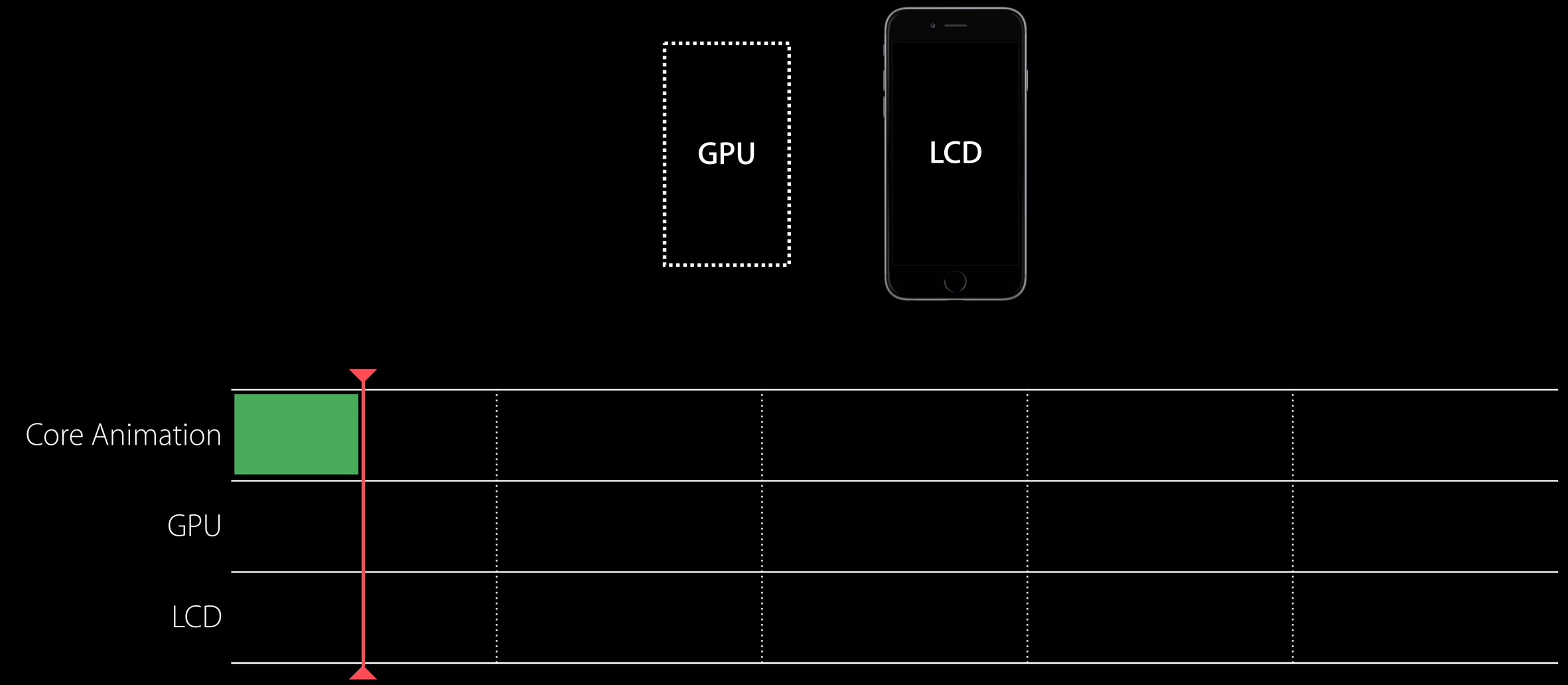

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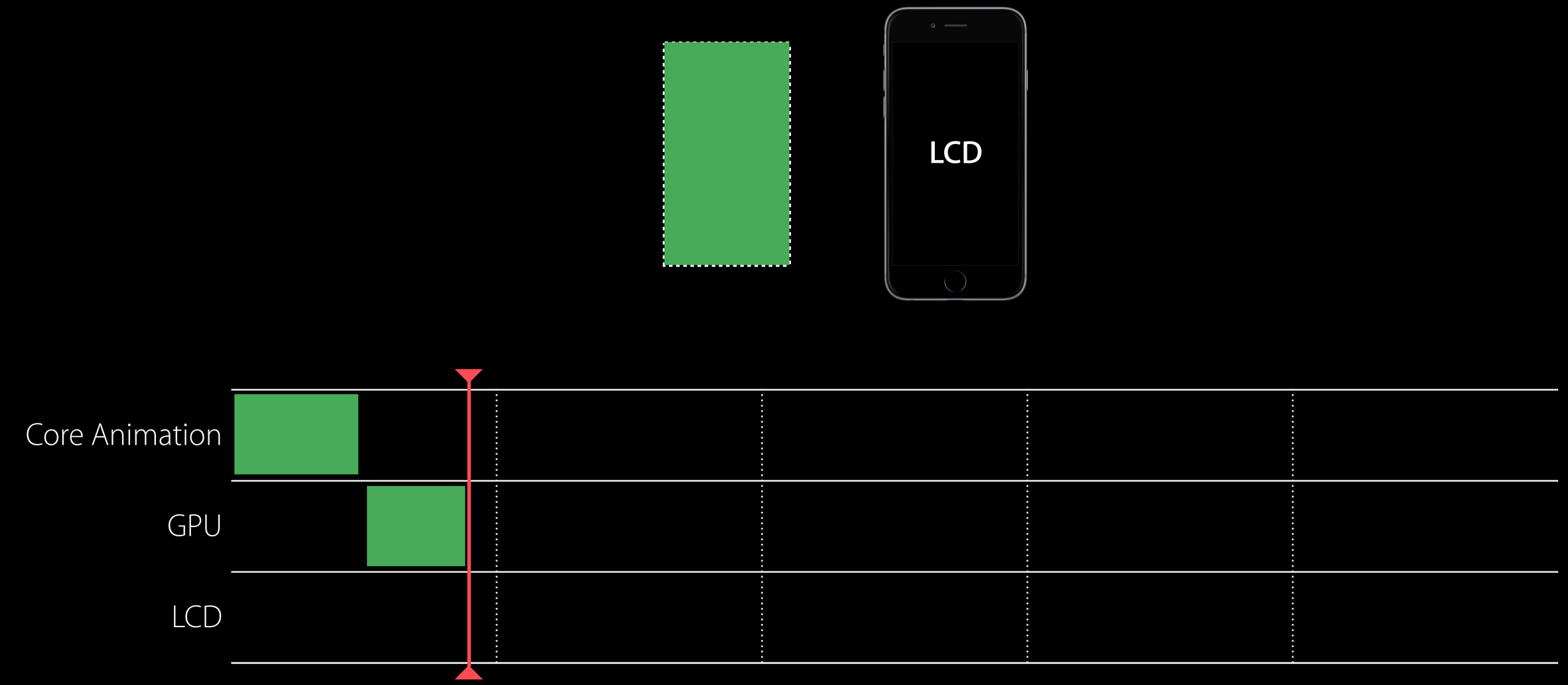

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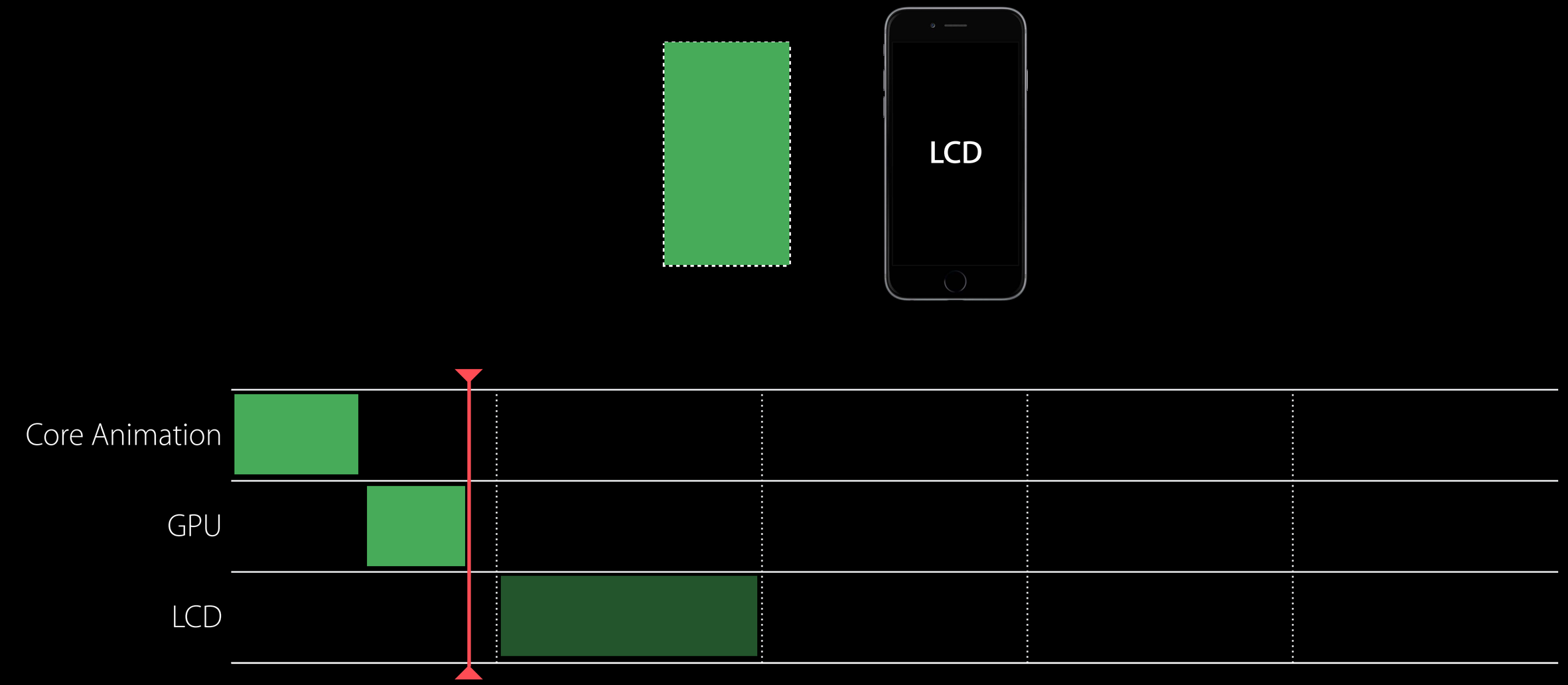

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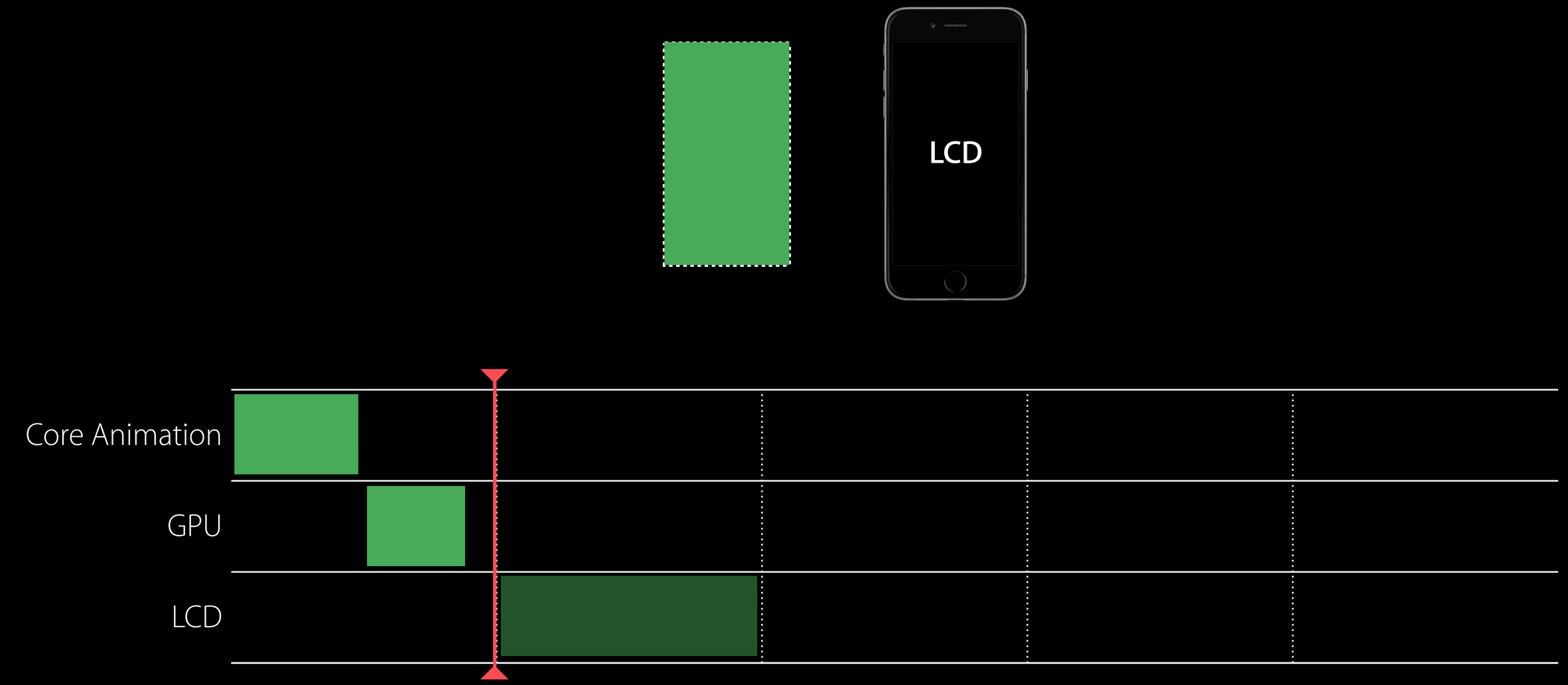

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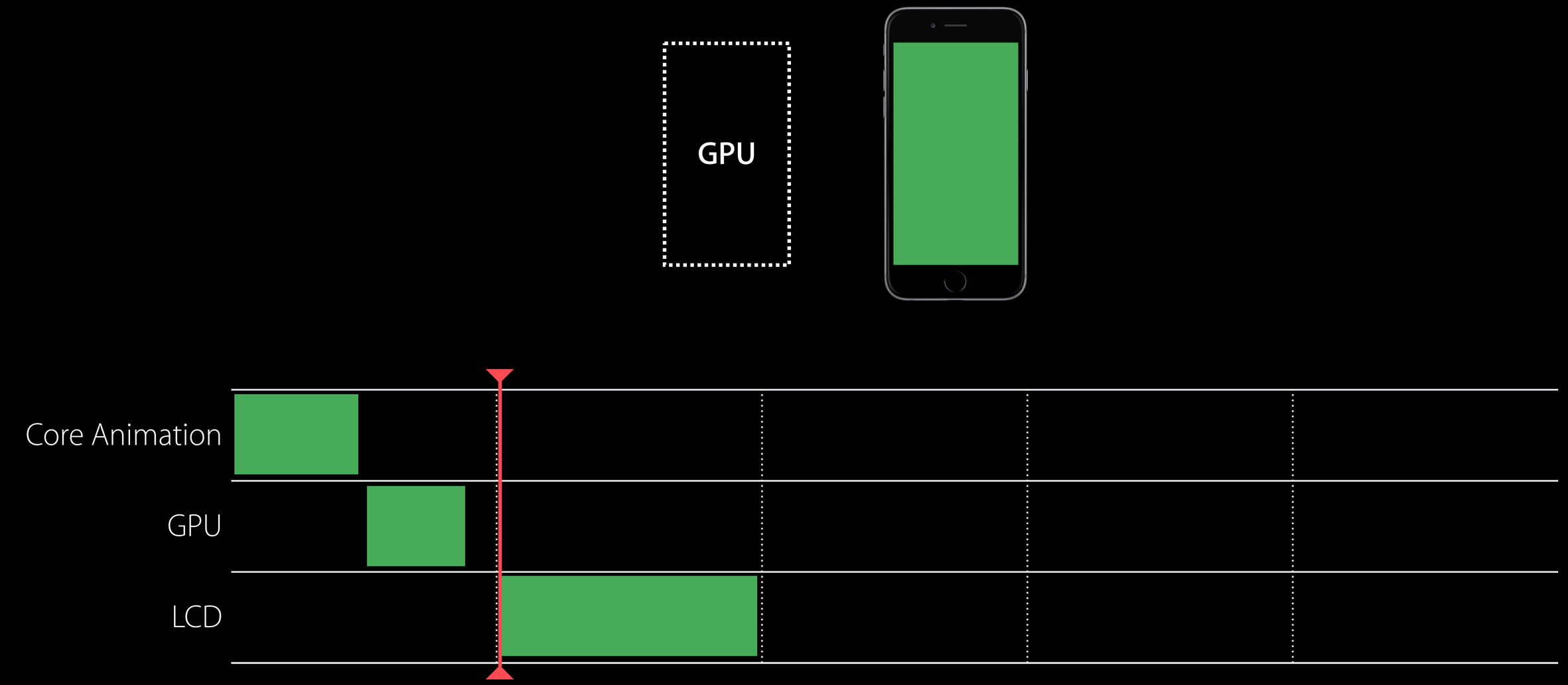

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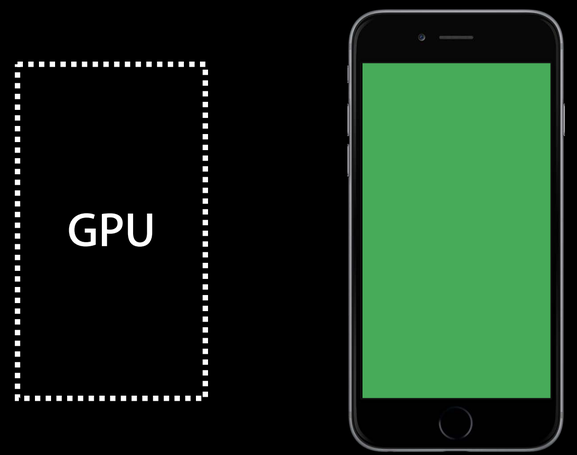

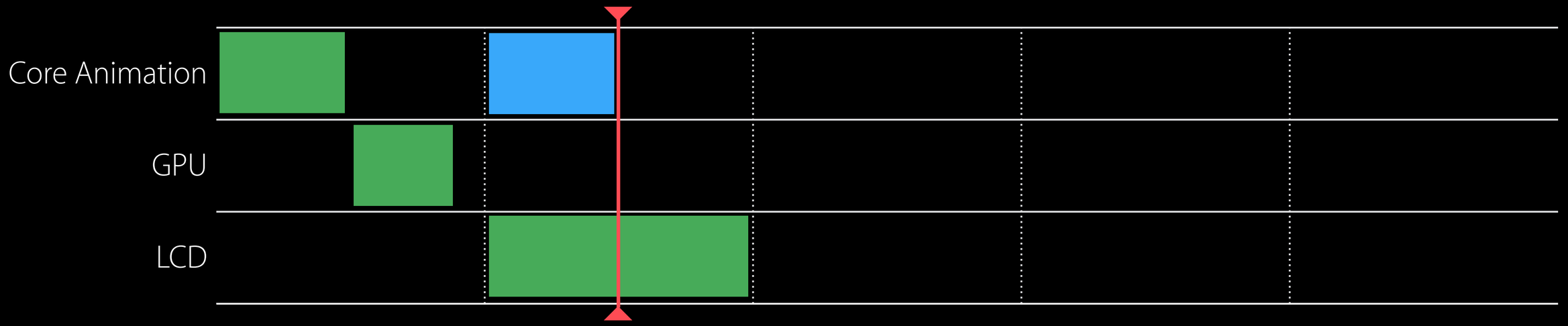

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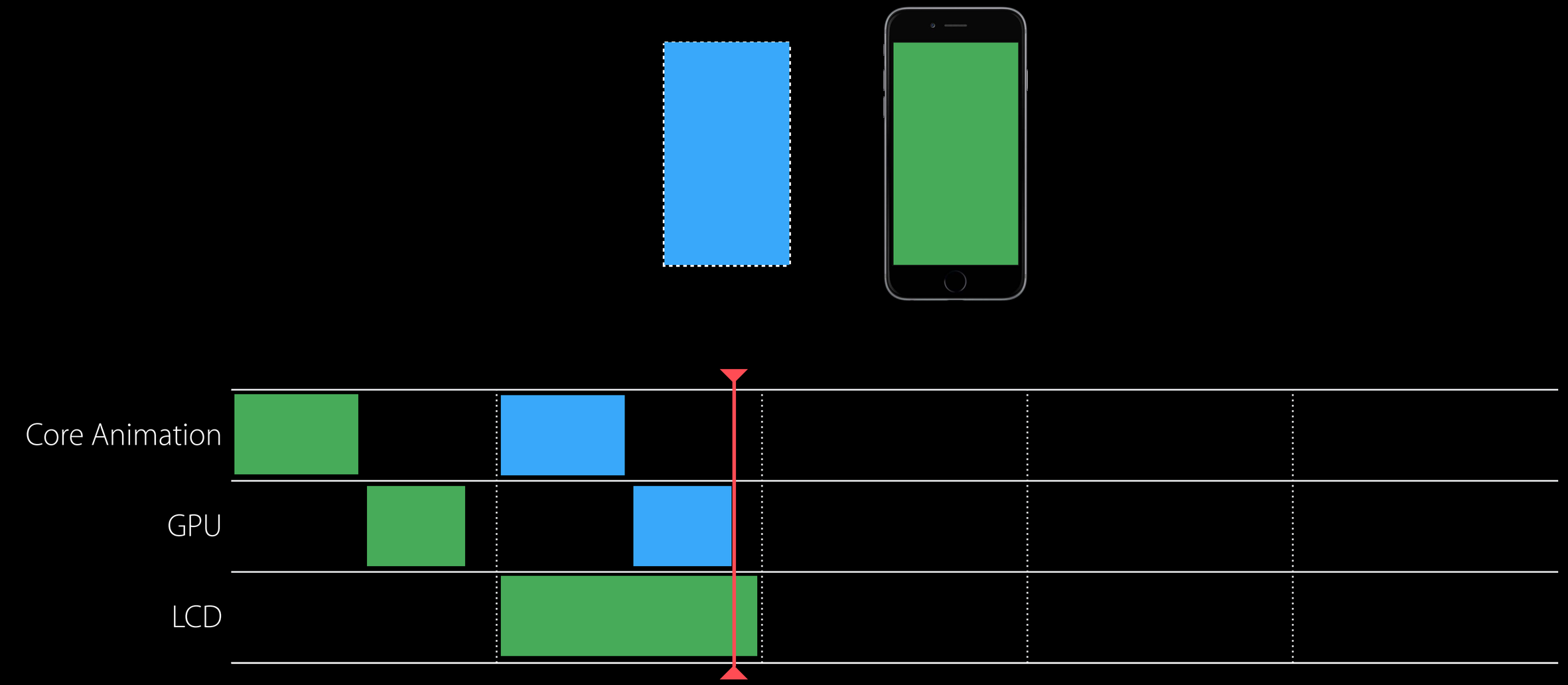

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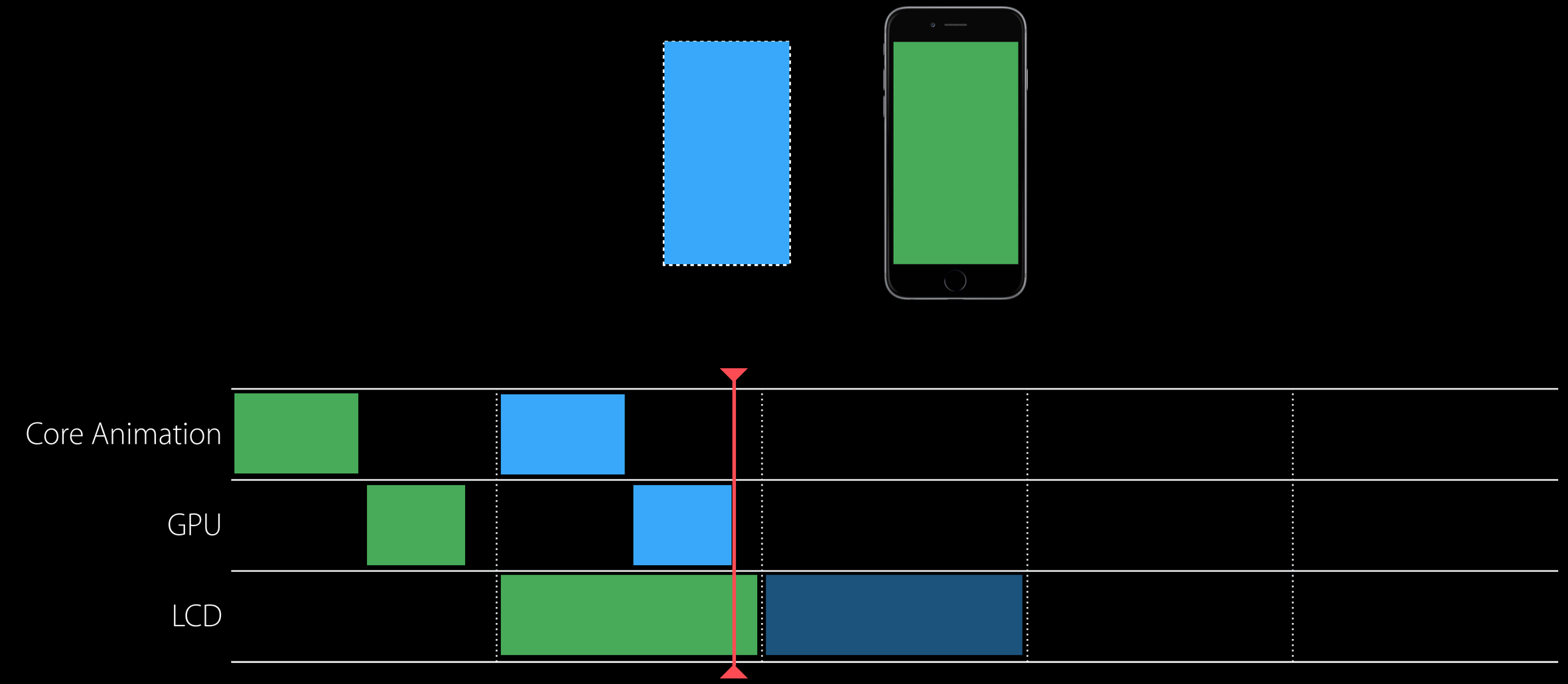

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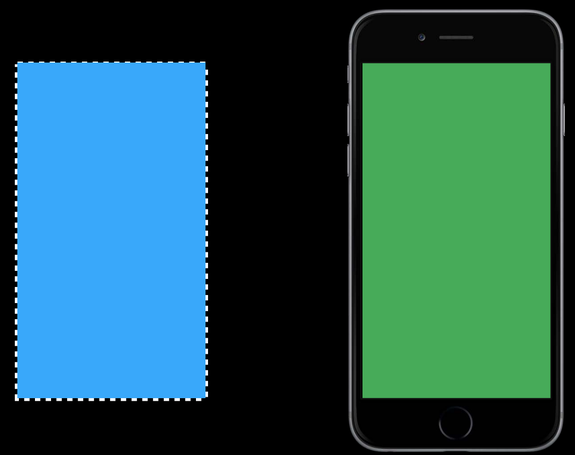

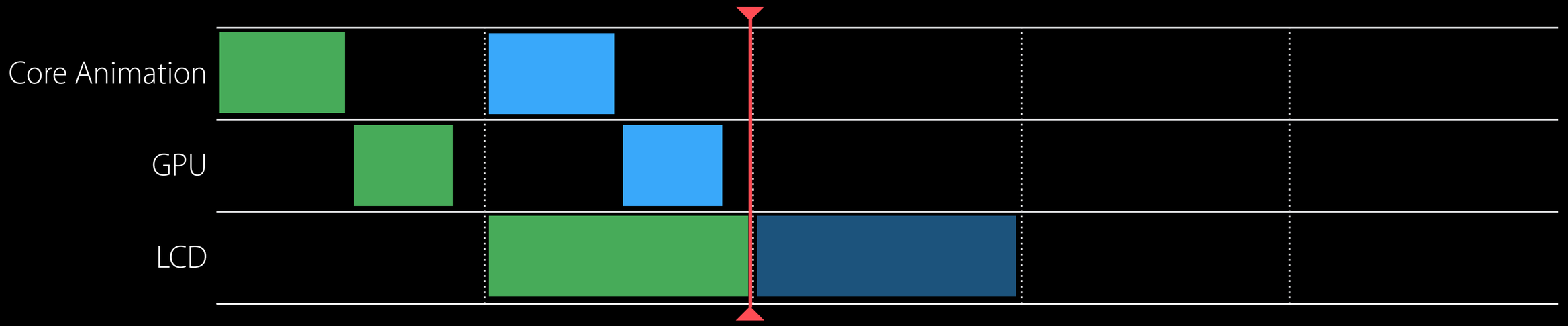

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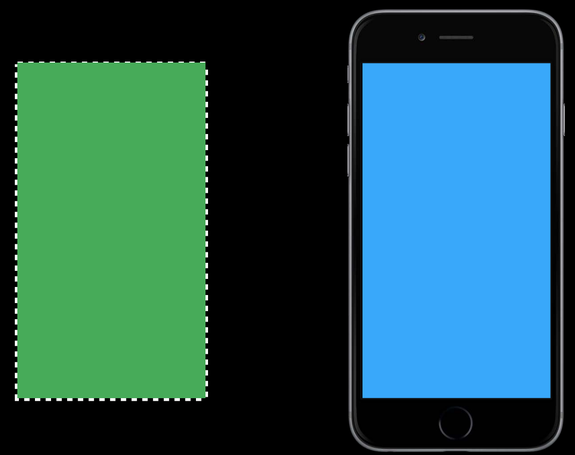

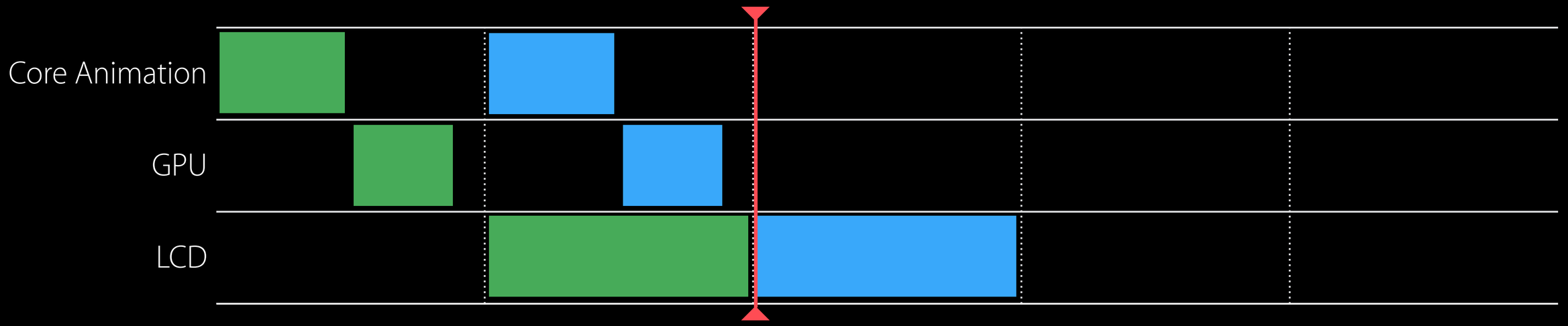

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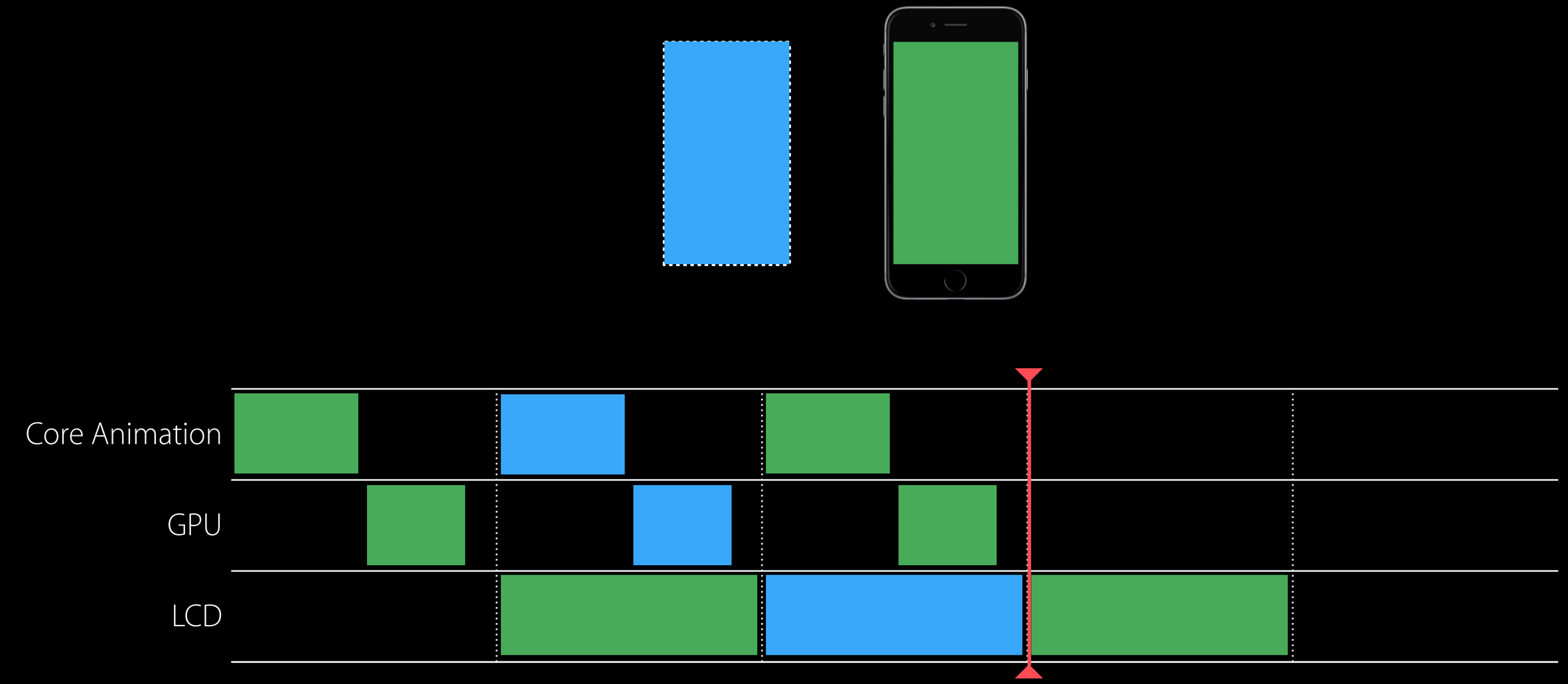

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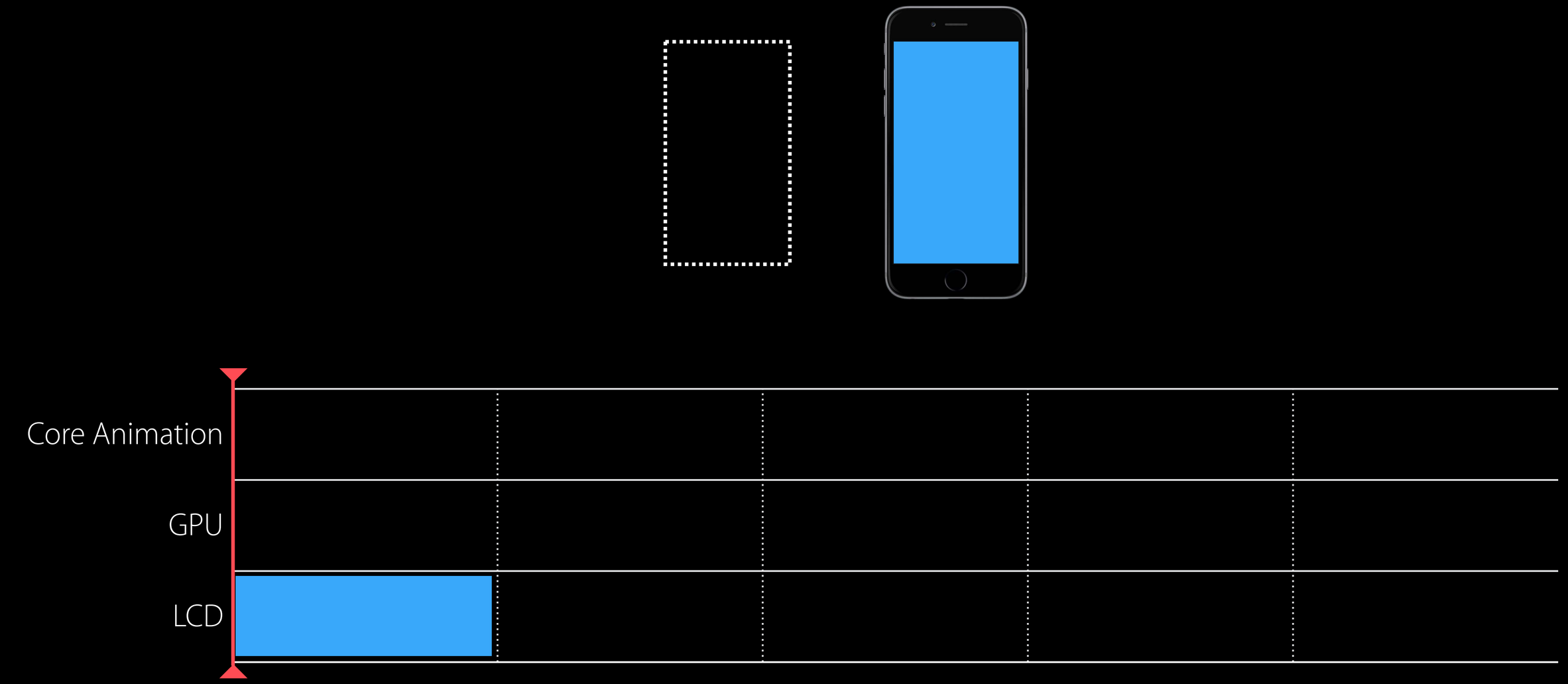

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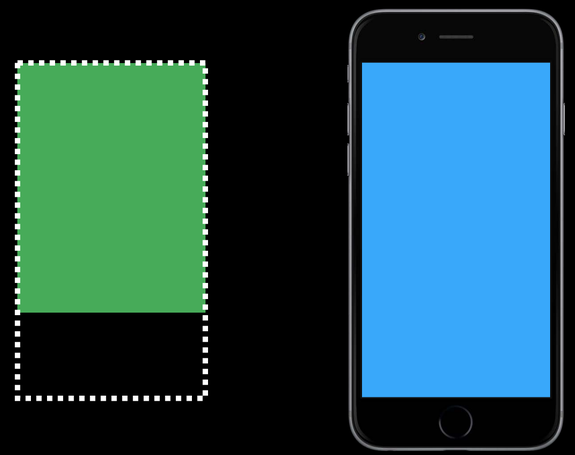

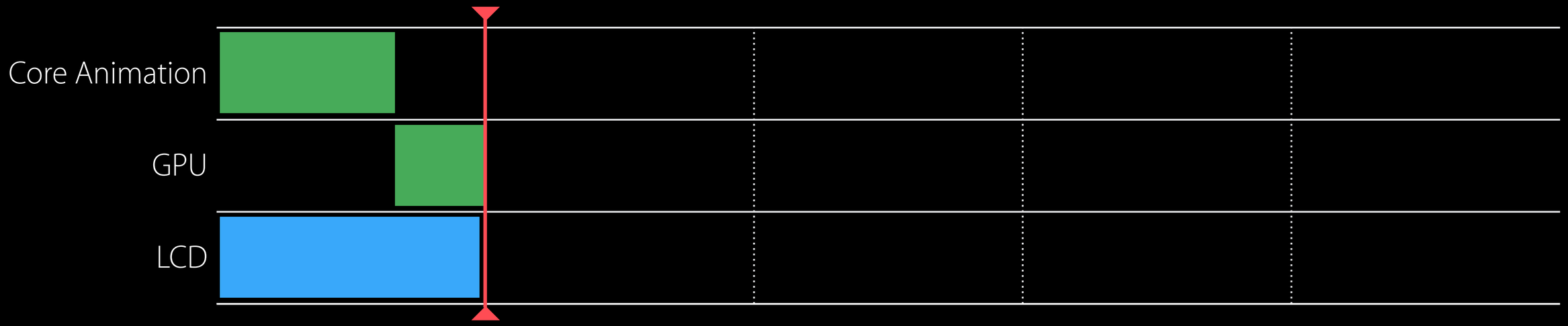

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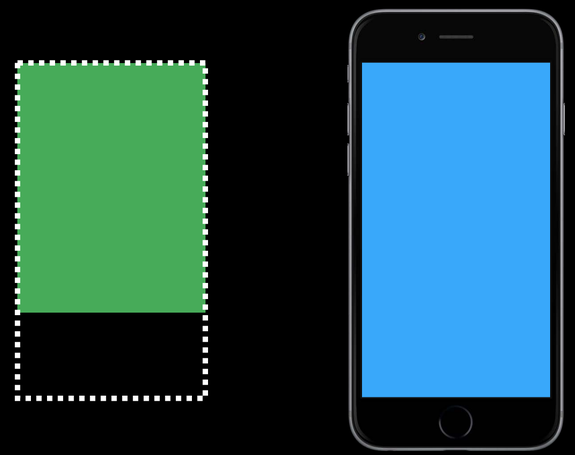

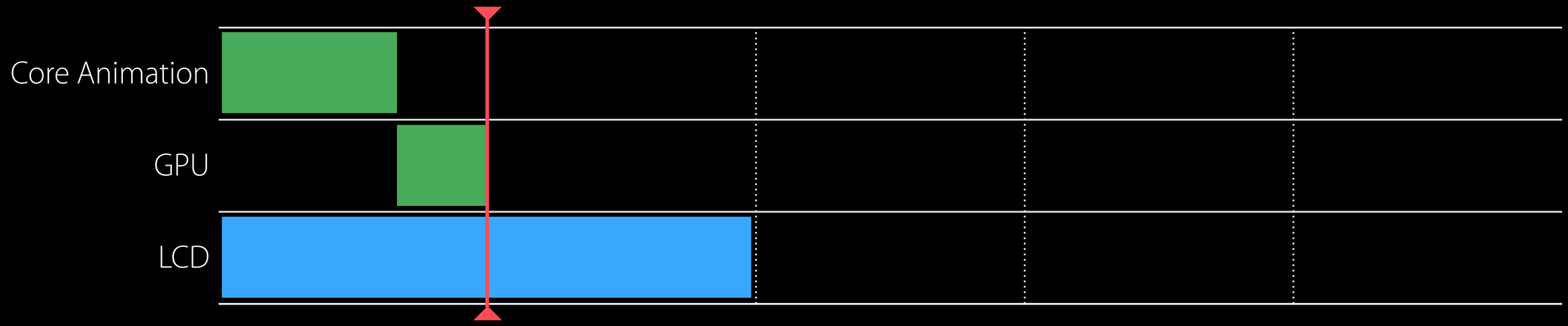

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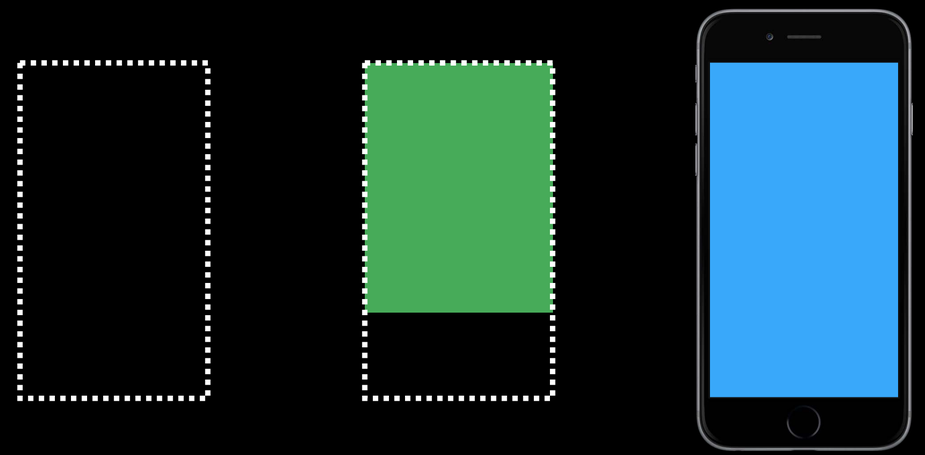

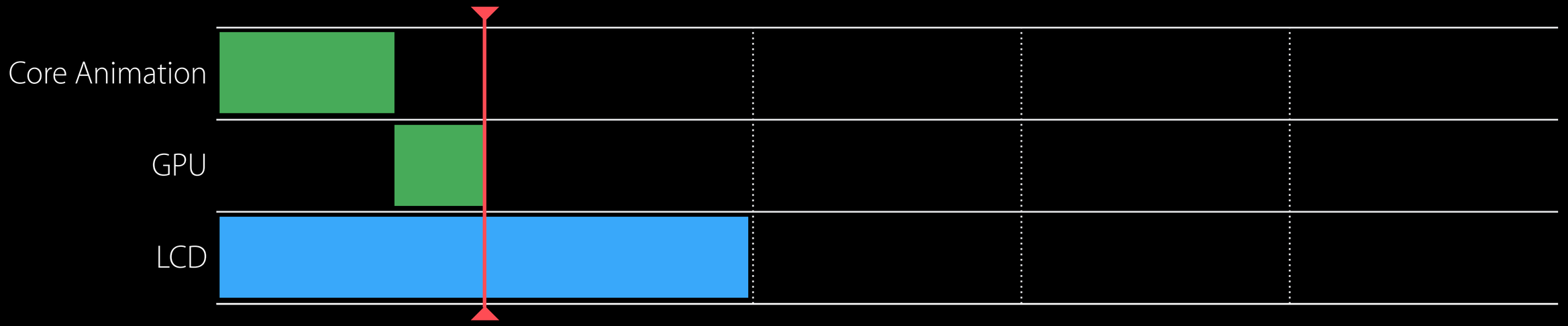

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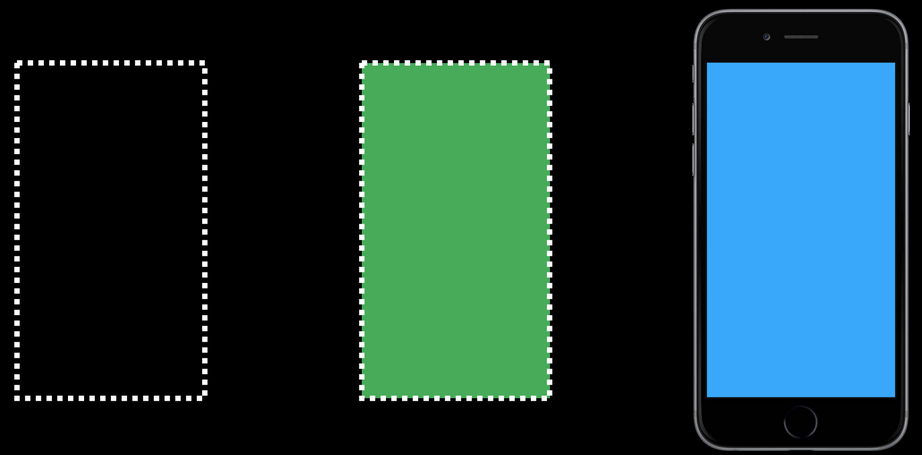
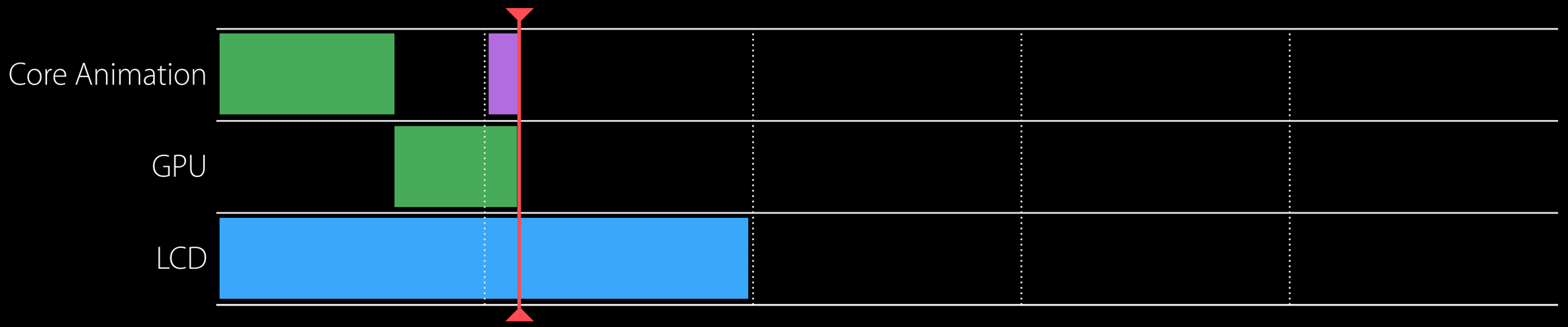
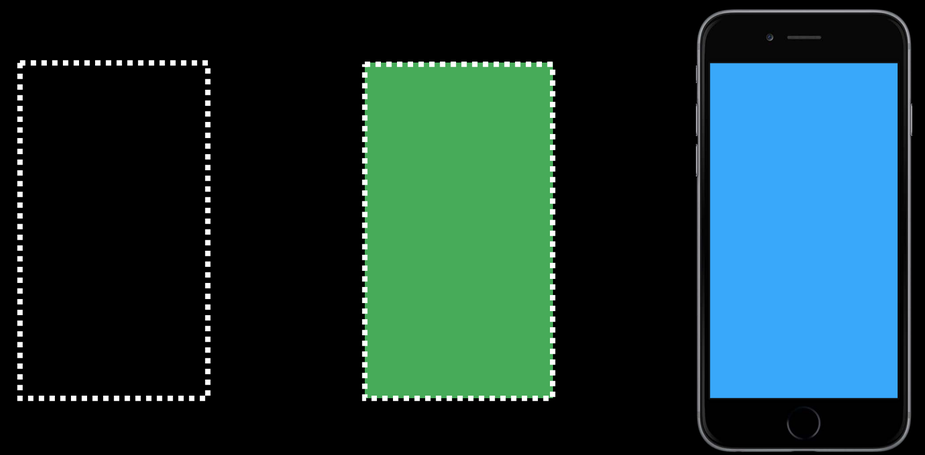
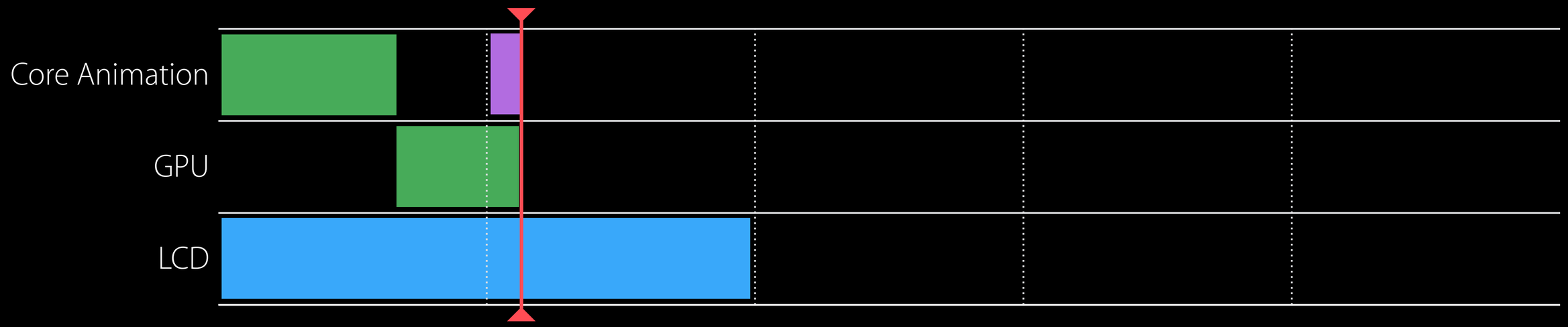




Triple Buffering





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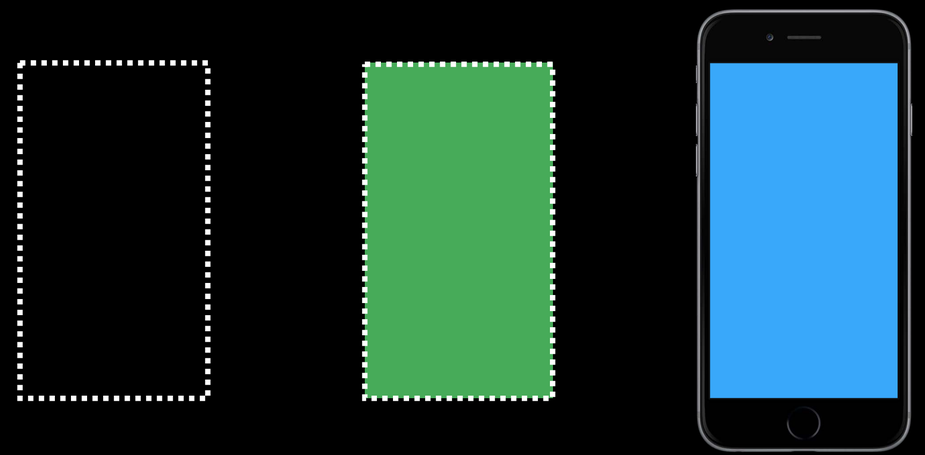

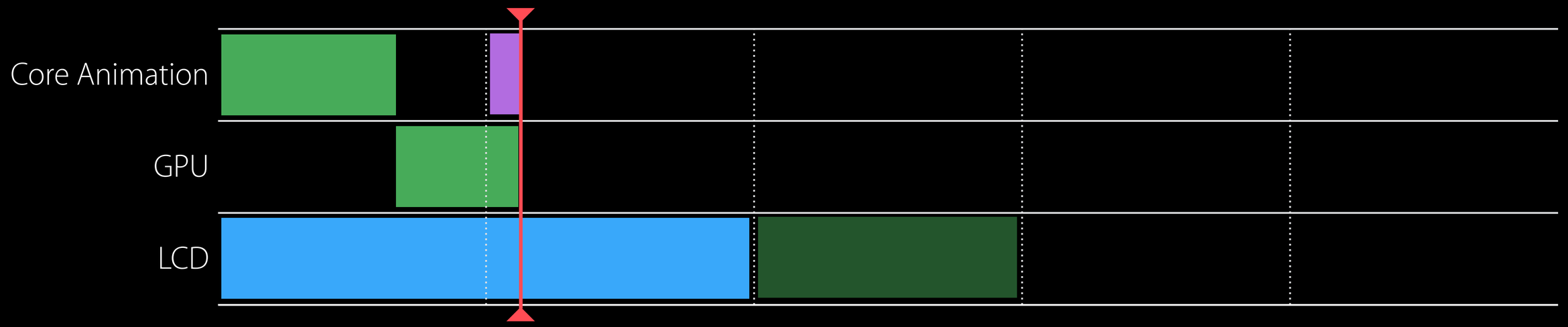

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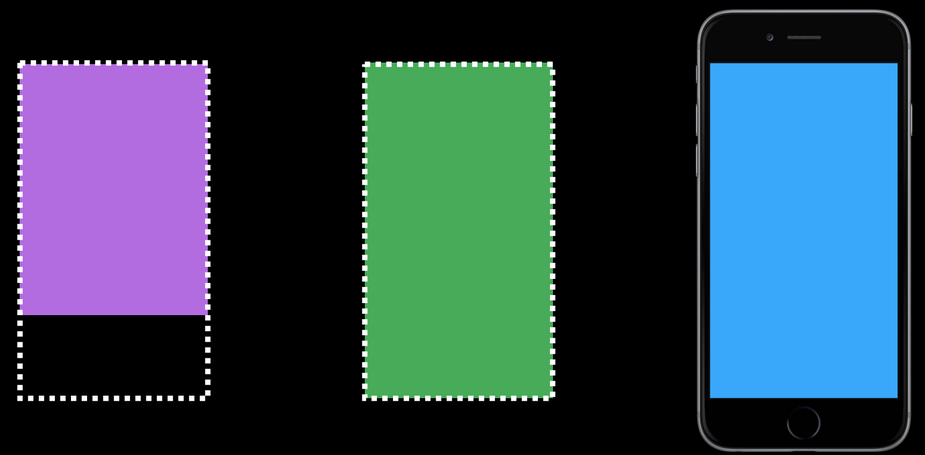

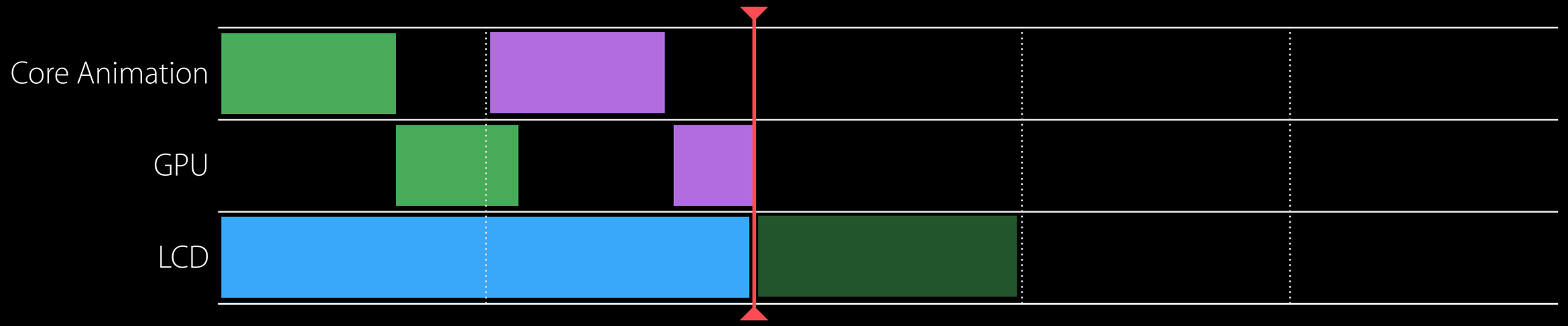

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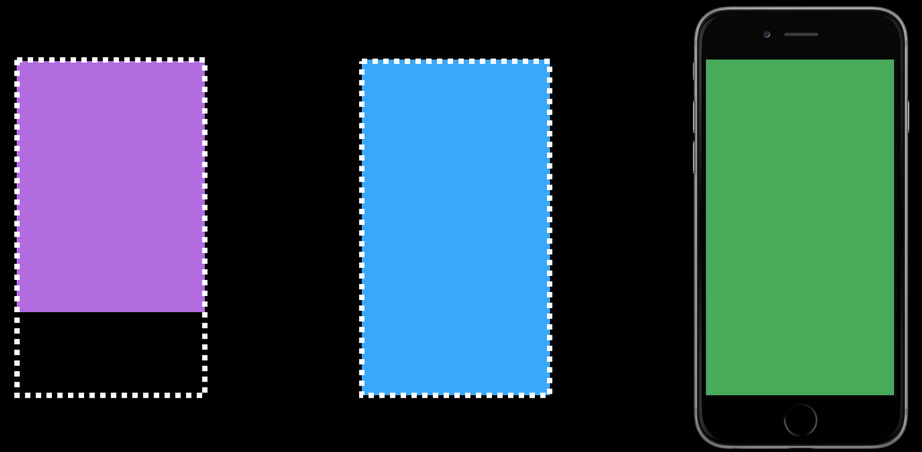

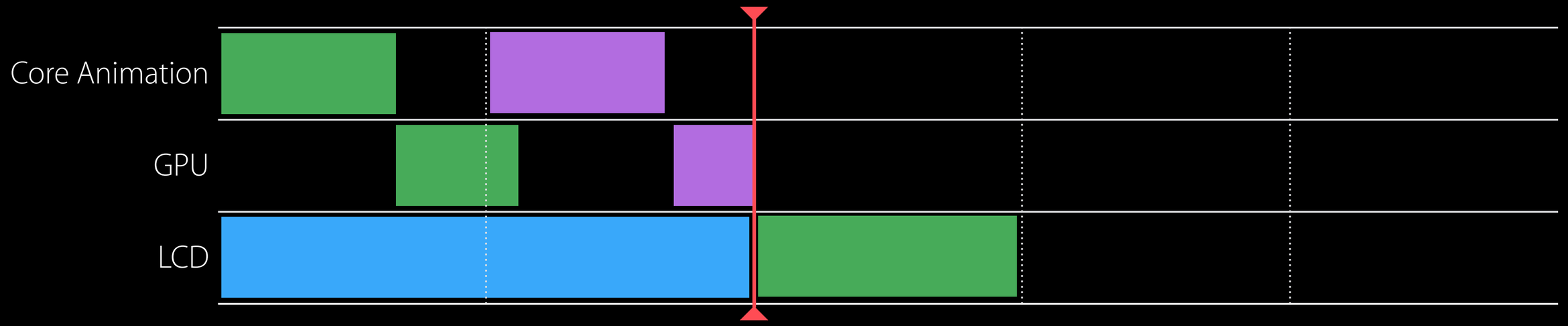

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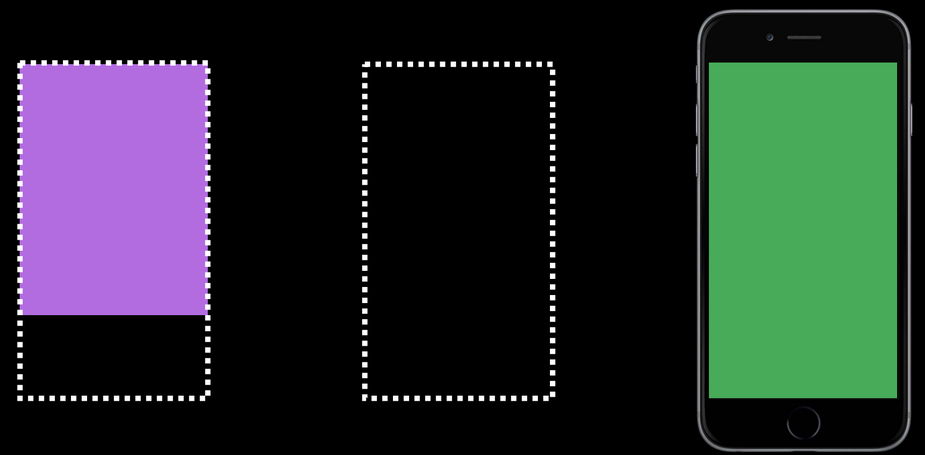

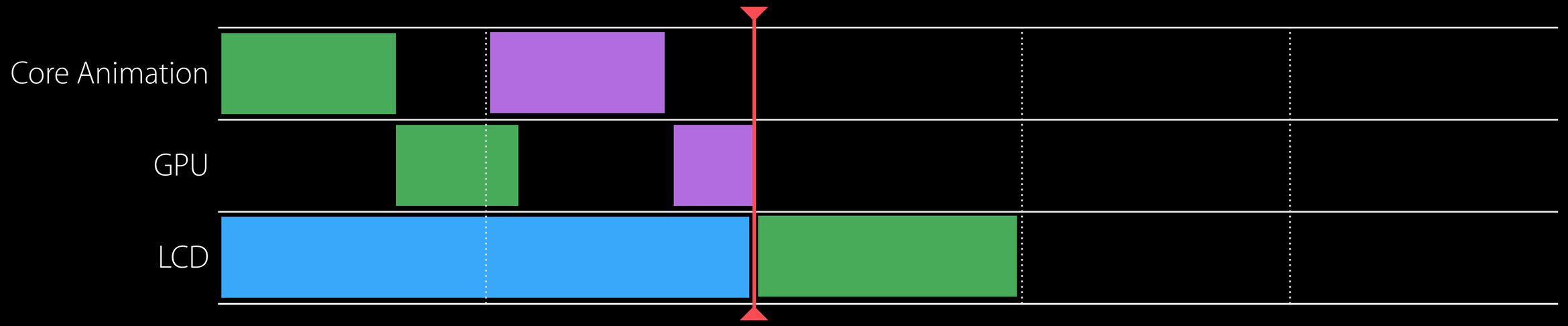

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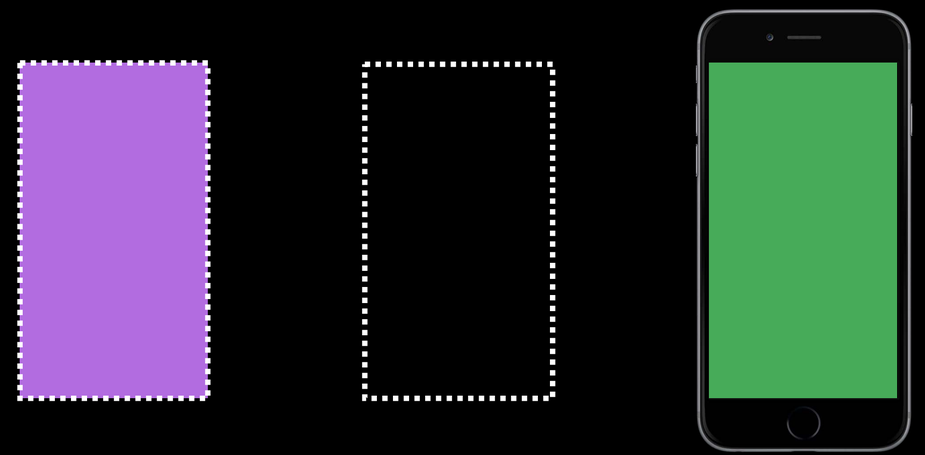

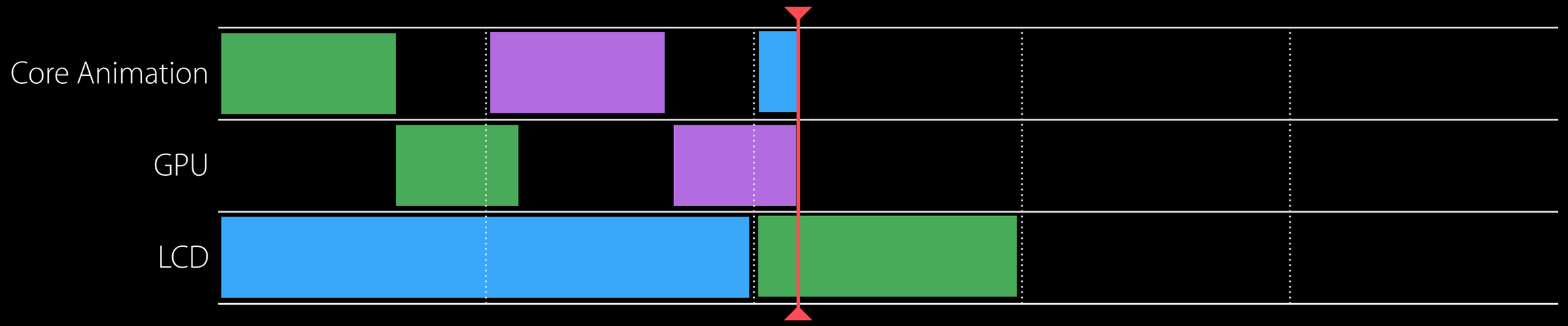

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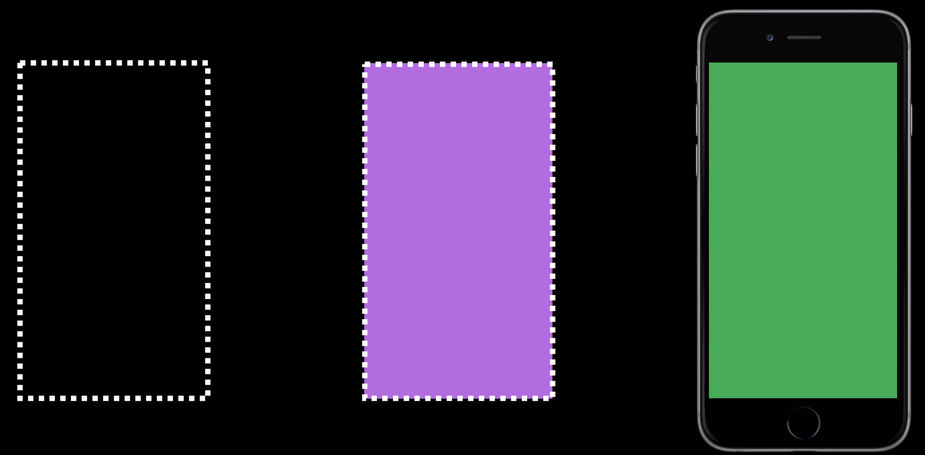
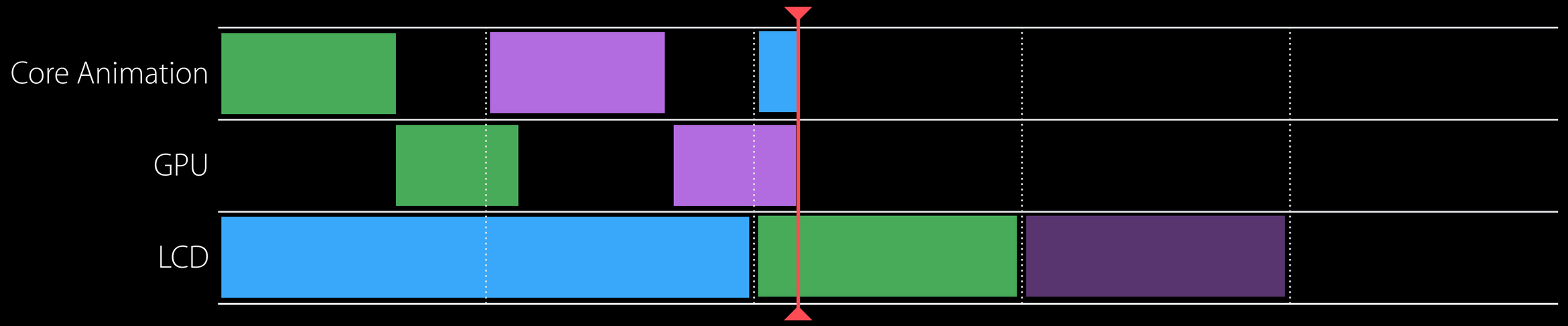
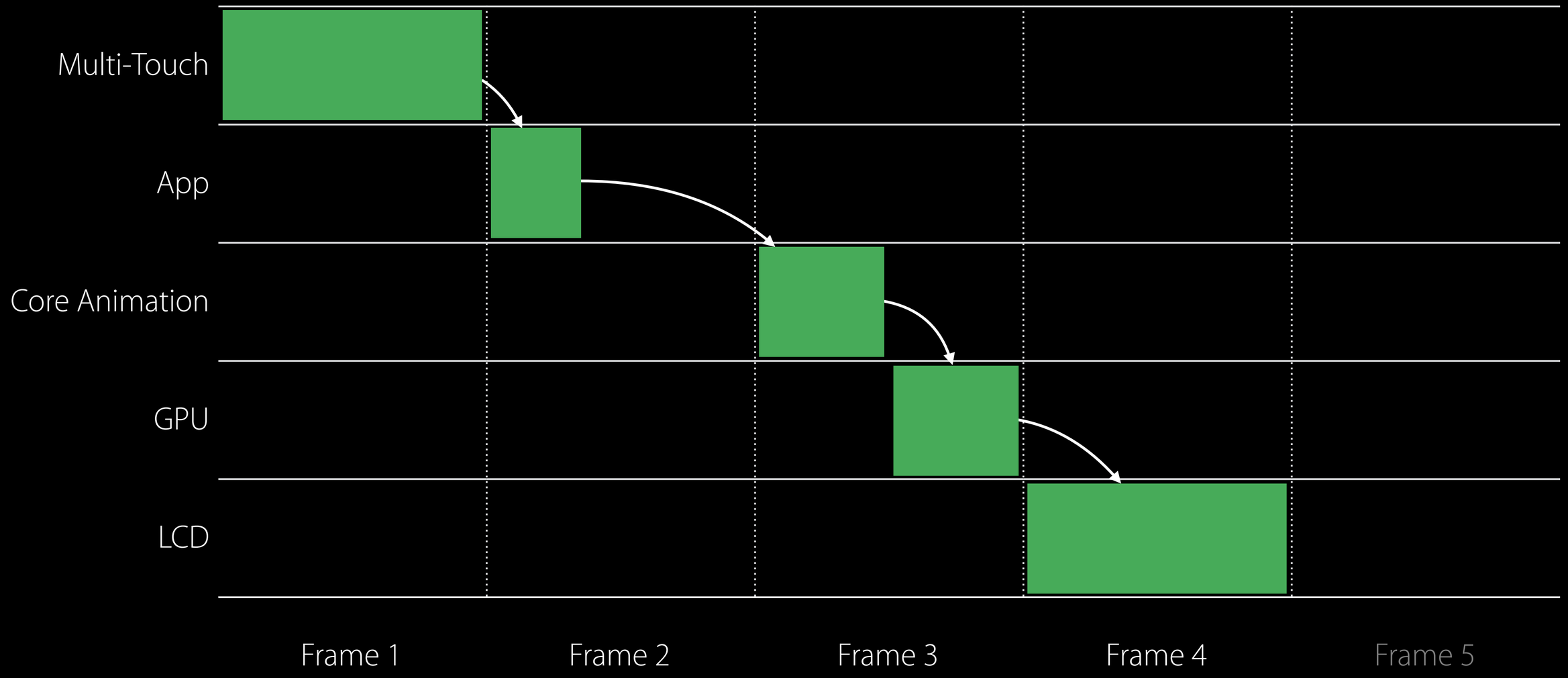




The iOS Touch and Graphics Pipeline

What About Metal and OpenGL?



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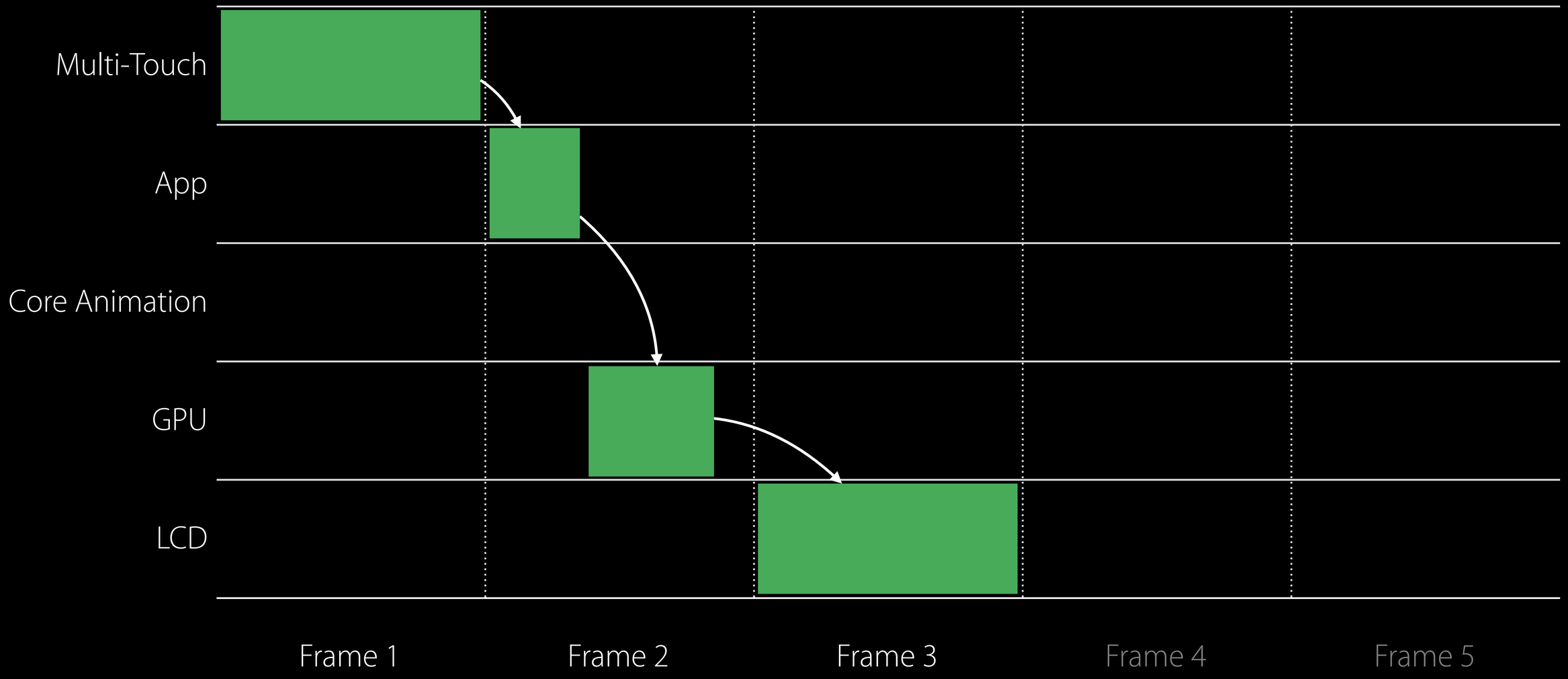

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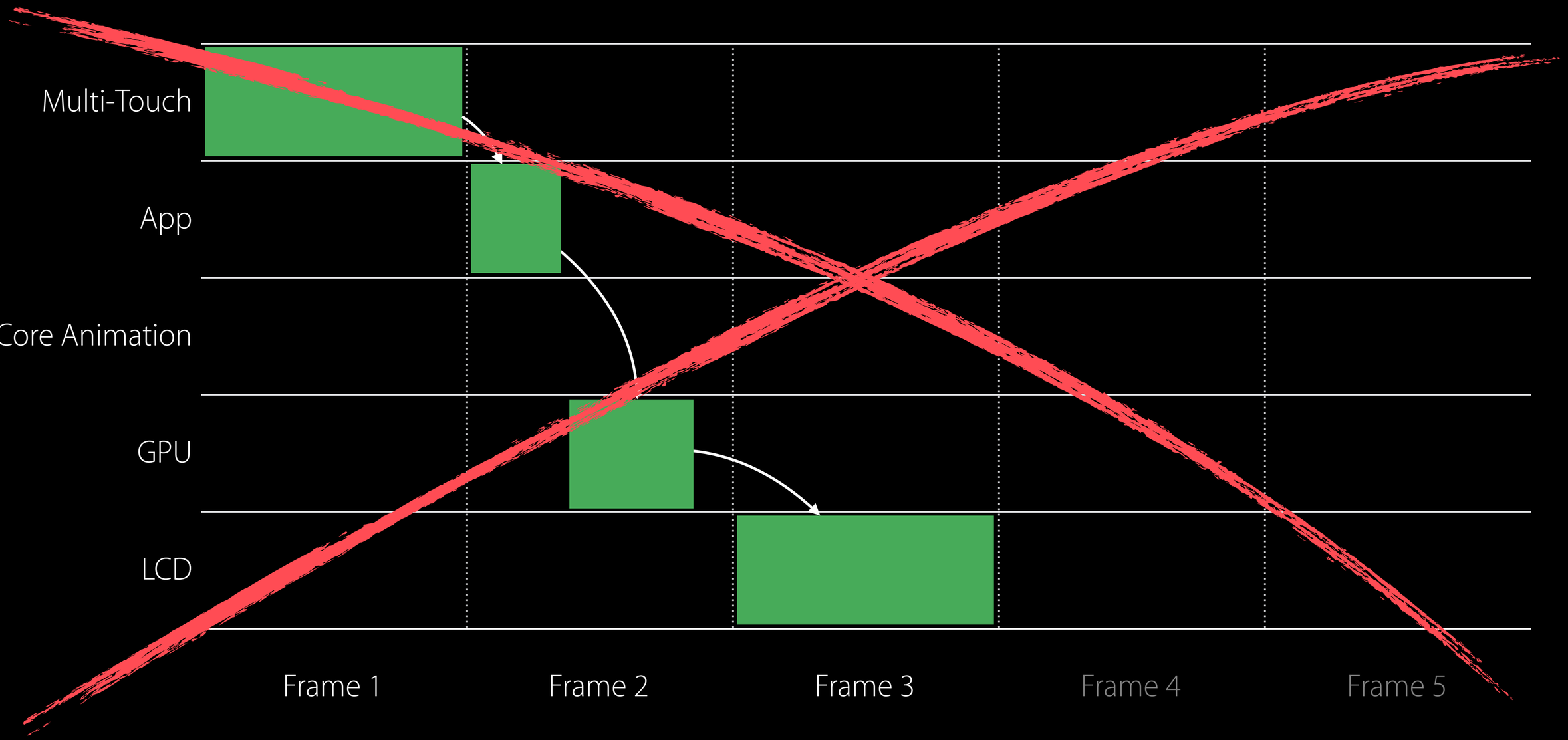

The iOS Touch and Graphics Pipeline

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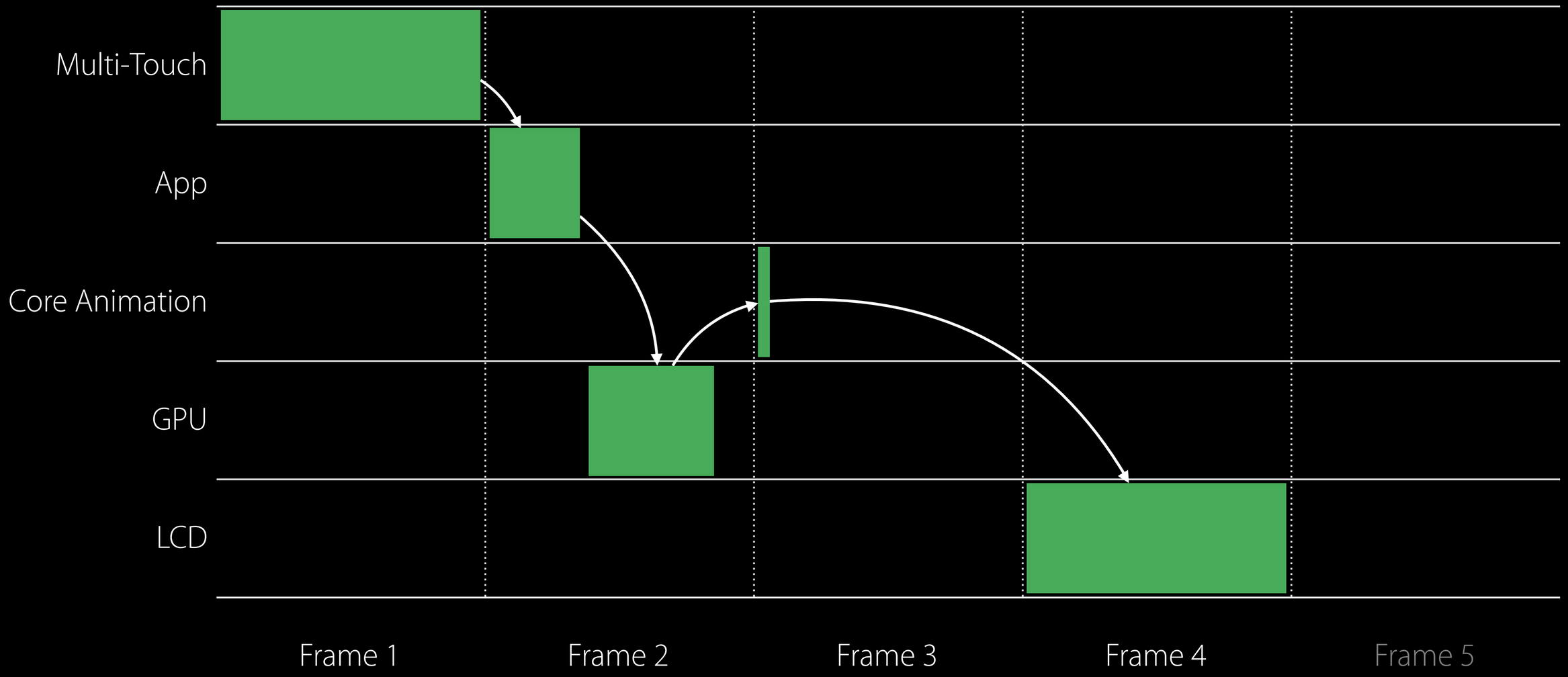
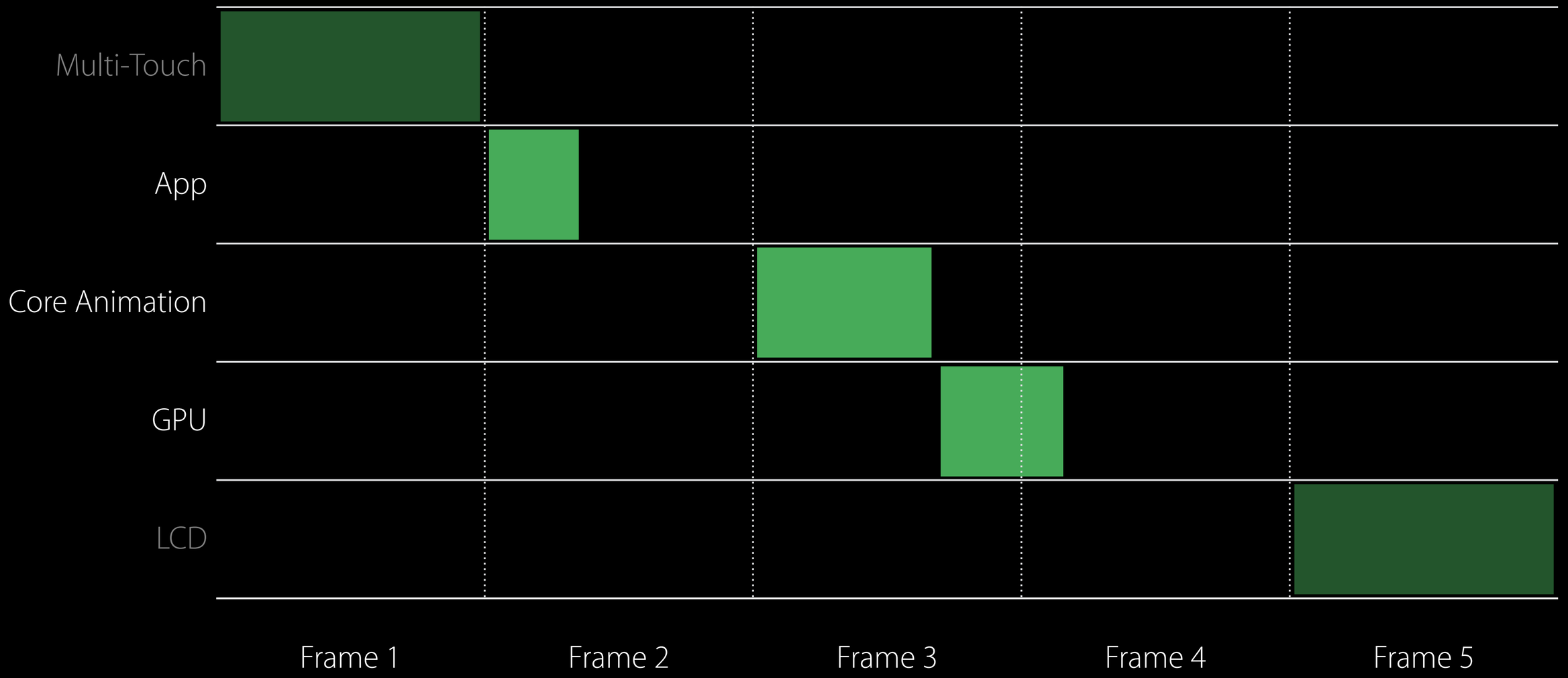
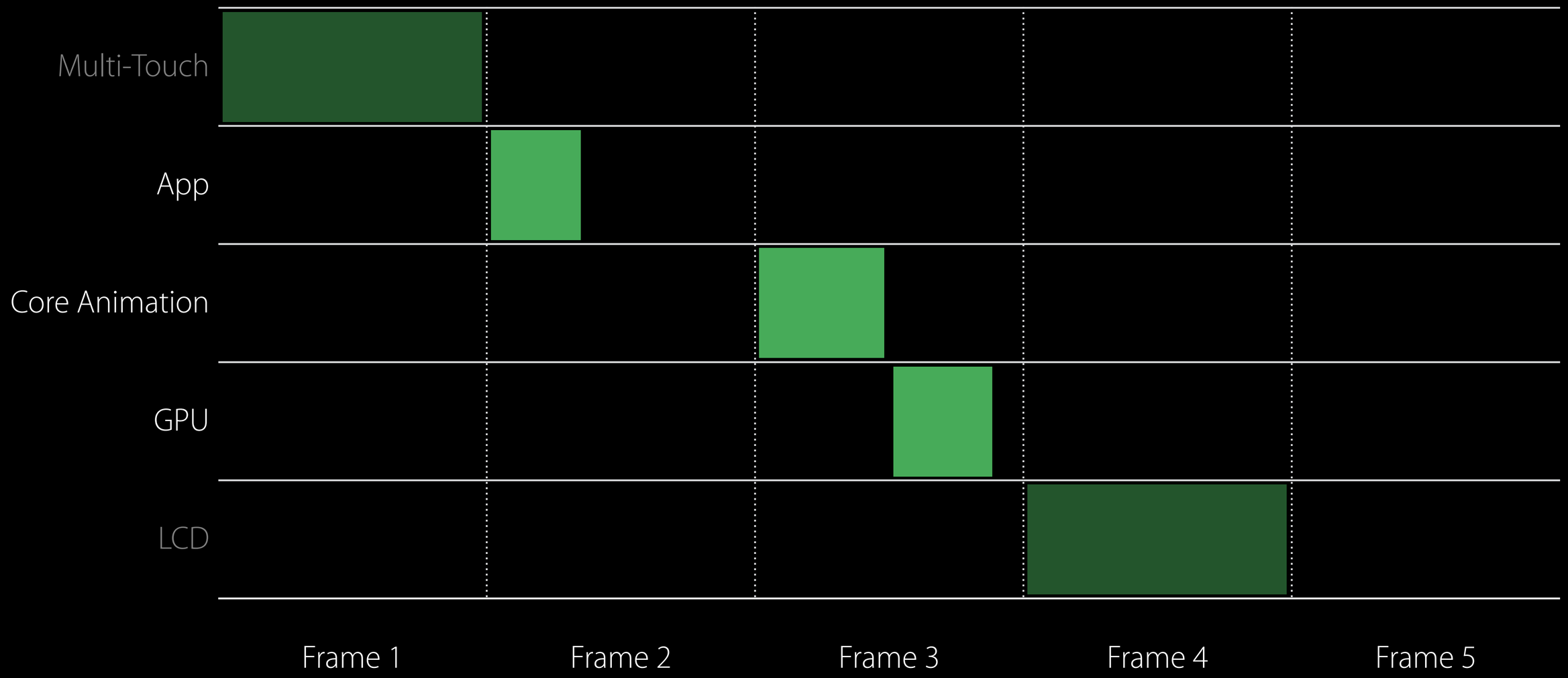


The iOS Touch and Graphics Pipeline

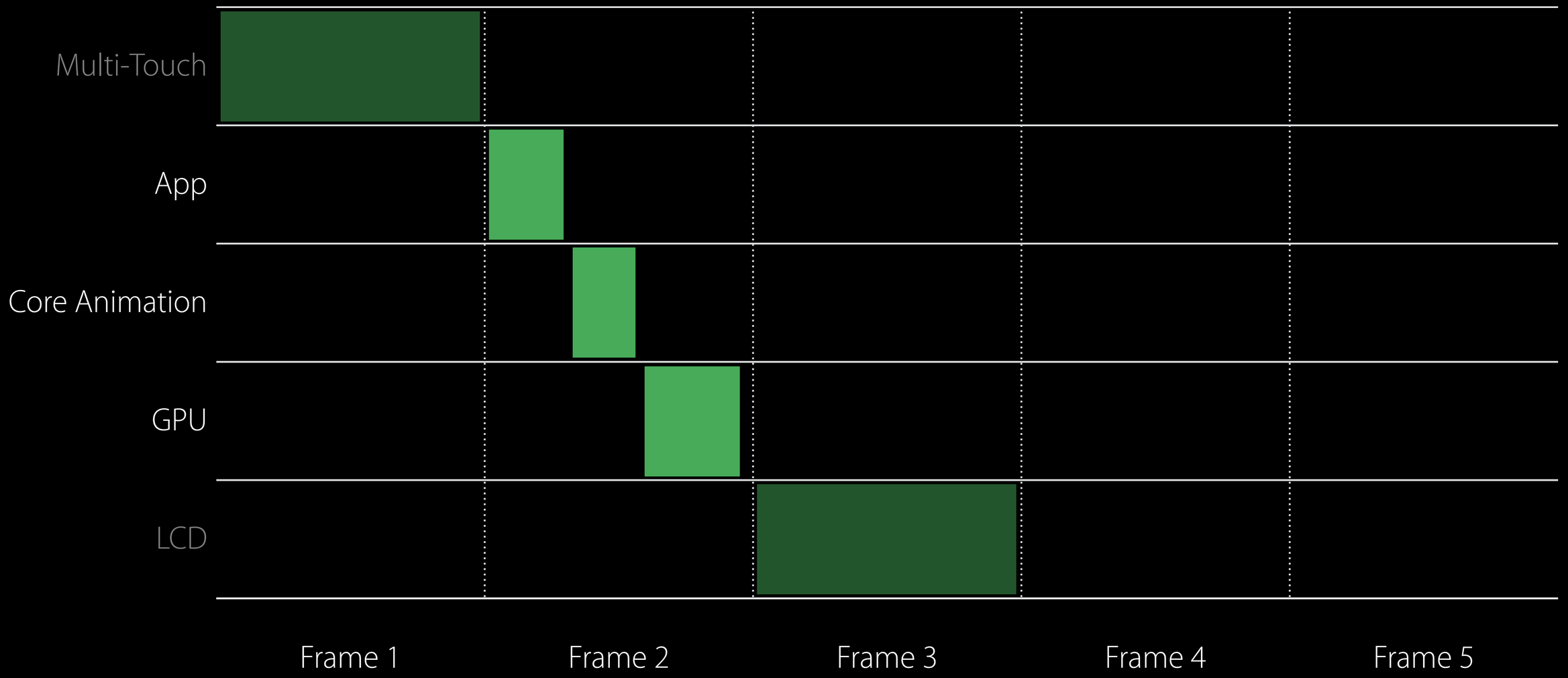


The iOS Touch and Graphics Pipeline



The iOS Touch and Graphics Pipeline

NEW



What's New

Jacob Xiao UIKit Engineer

What’s New

What's New

NEW

Low Latency Core Animation

What's New

NEW

Low Latency Core Animation

Touch Coalescing

What's New

NEW

Low Latency Core Animation

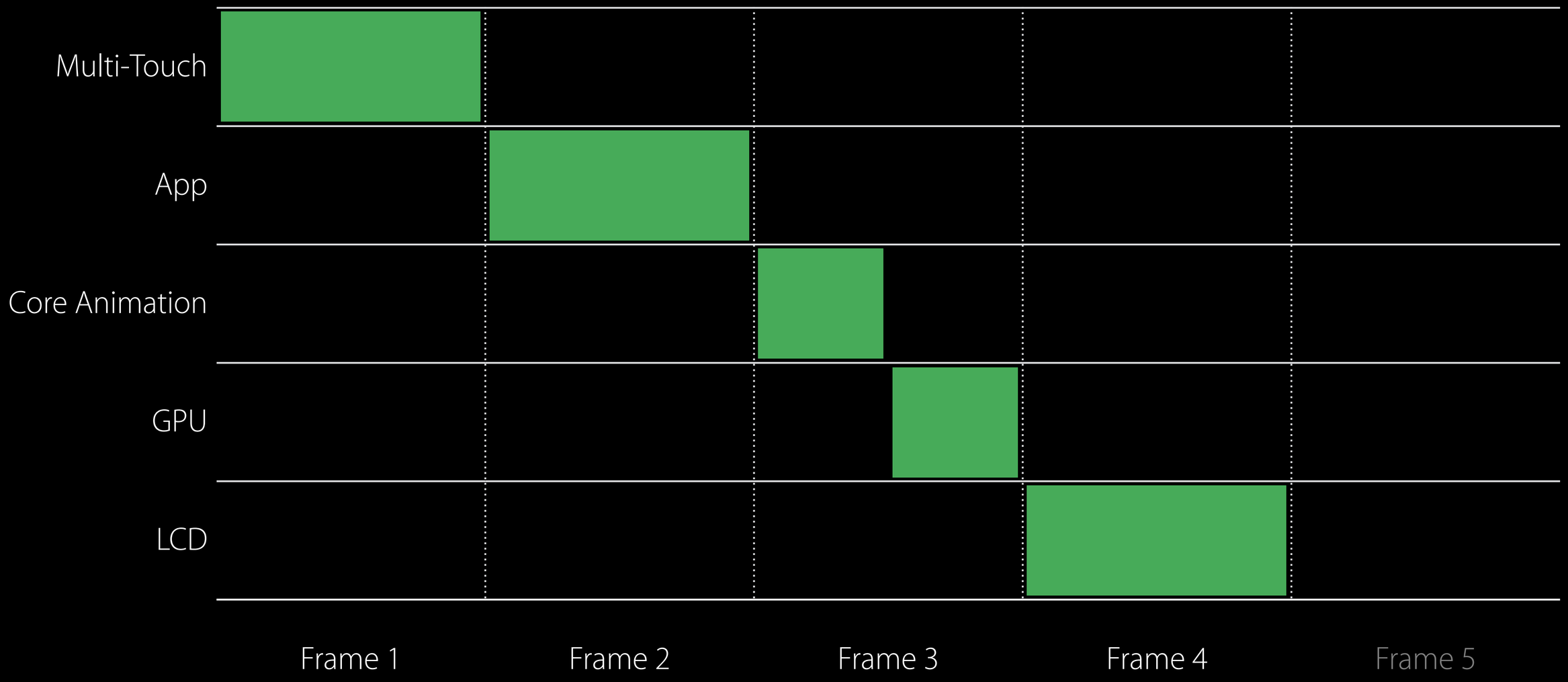
Touch Coalescing

Touch Prediction

Low Latency Core Animation

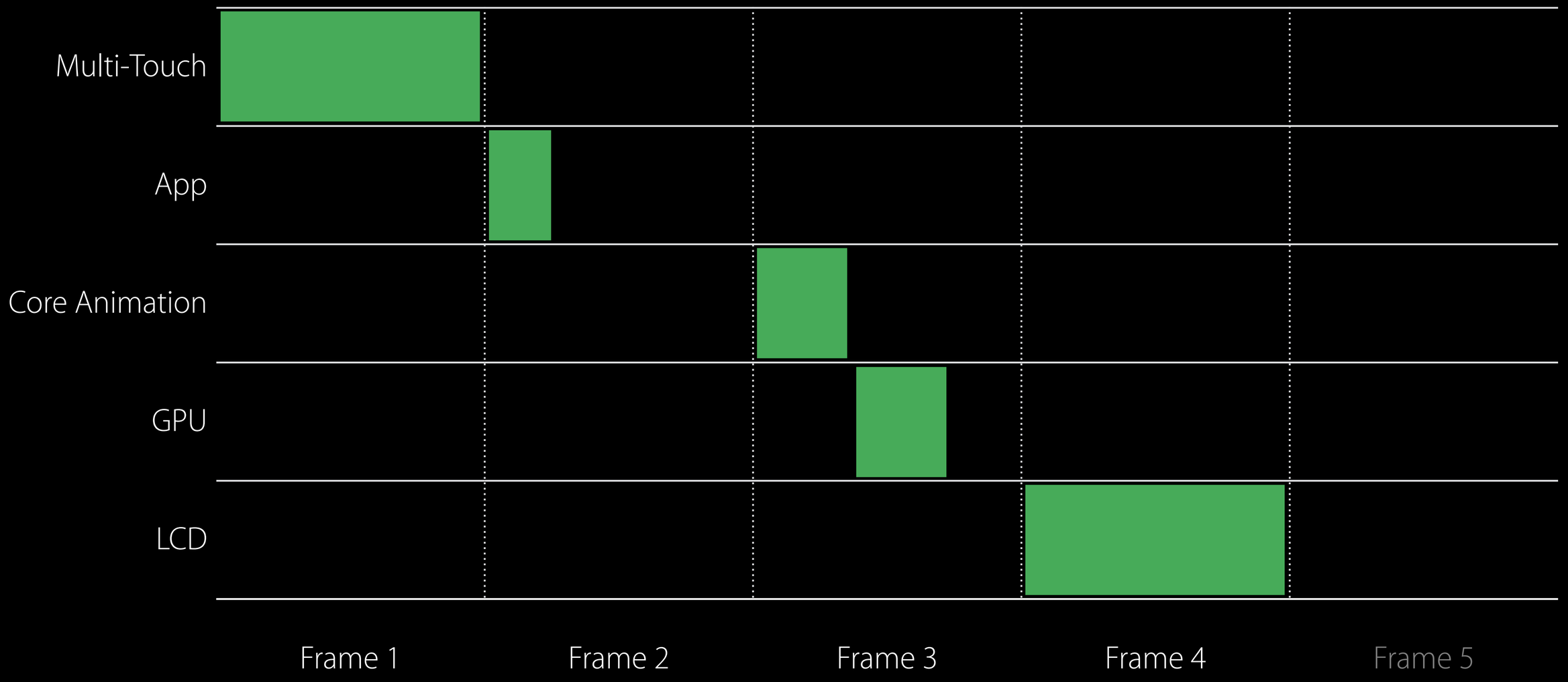
Low Latency Core Animation

iOS 8



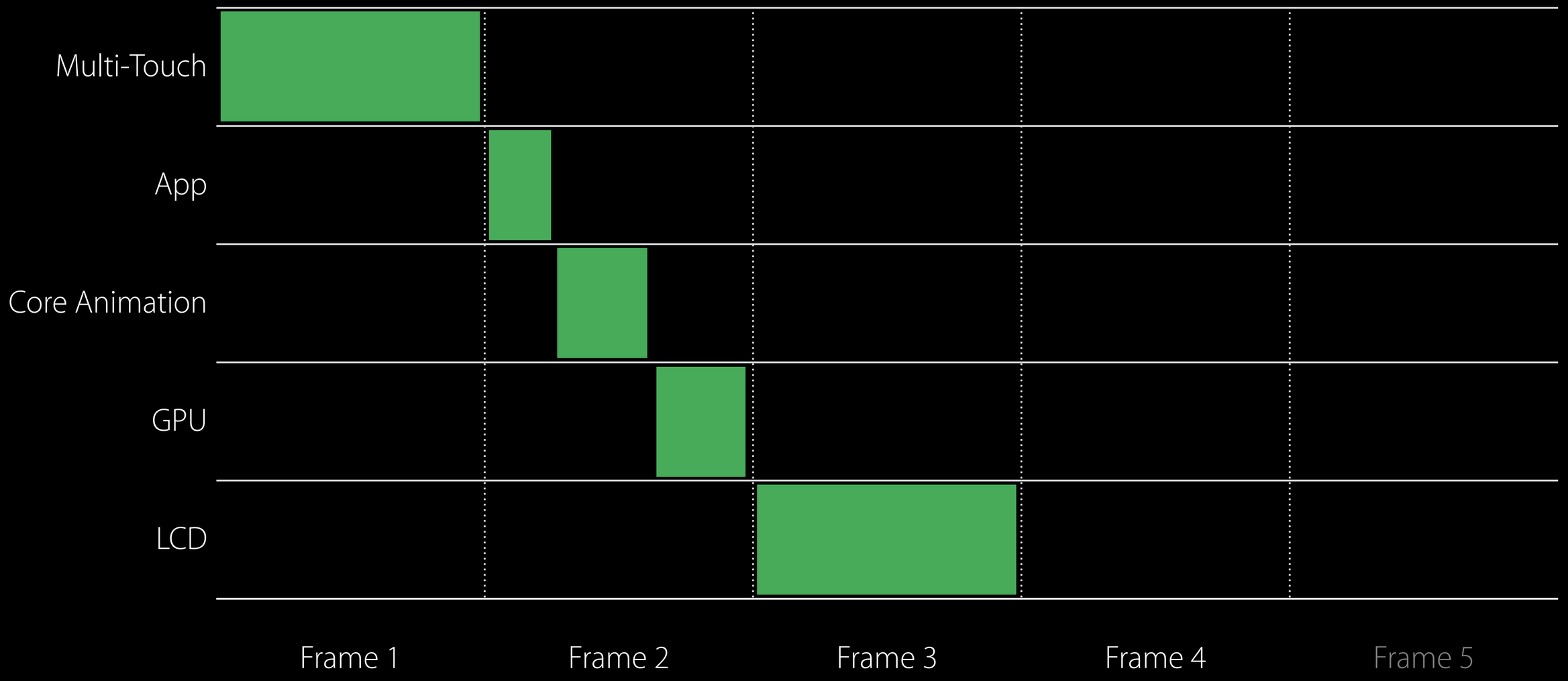
Low Latency Core Animation

iOS 8



Low Latency Core Animation

iOS 9



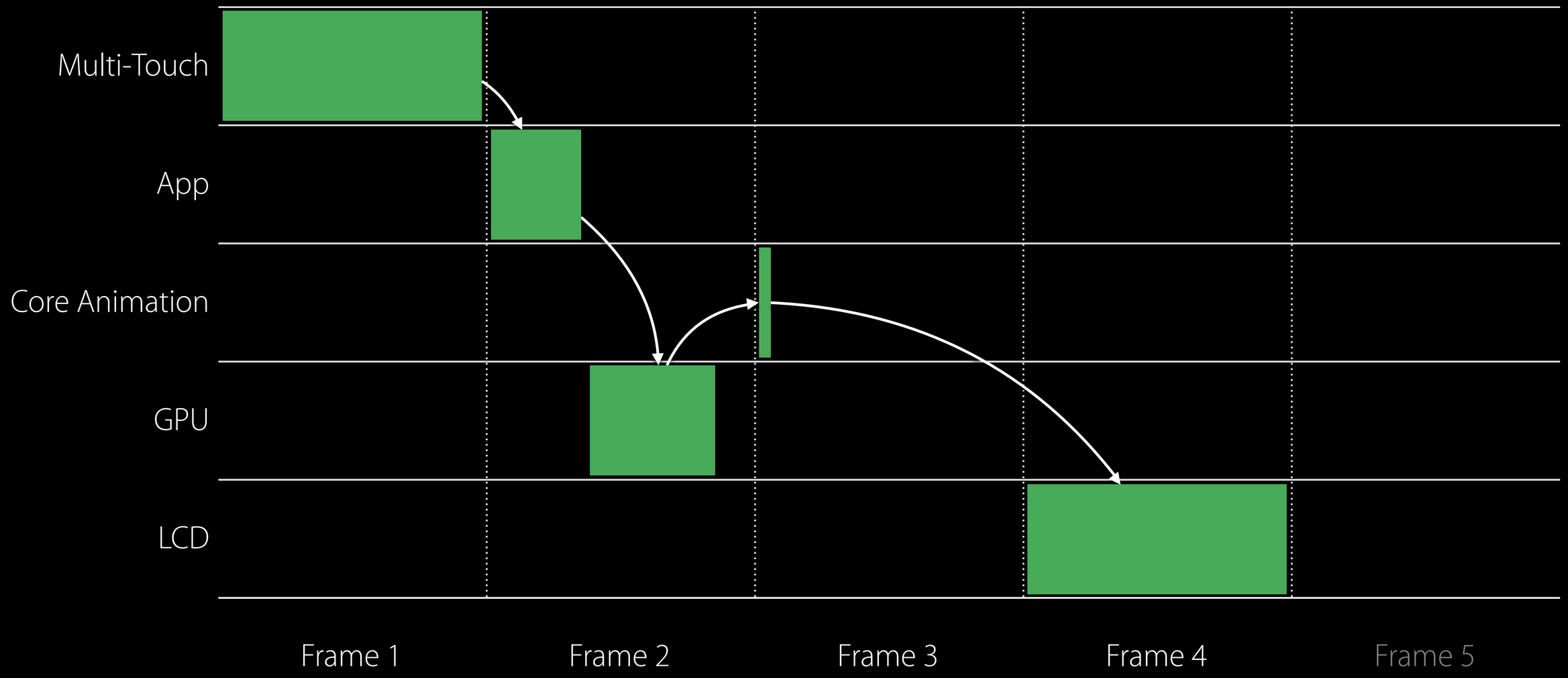
Low Latency Core Animation

Disabled for animations

- CAAnimations
- UIView animations

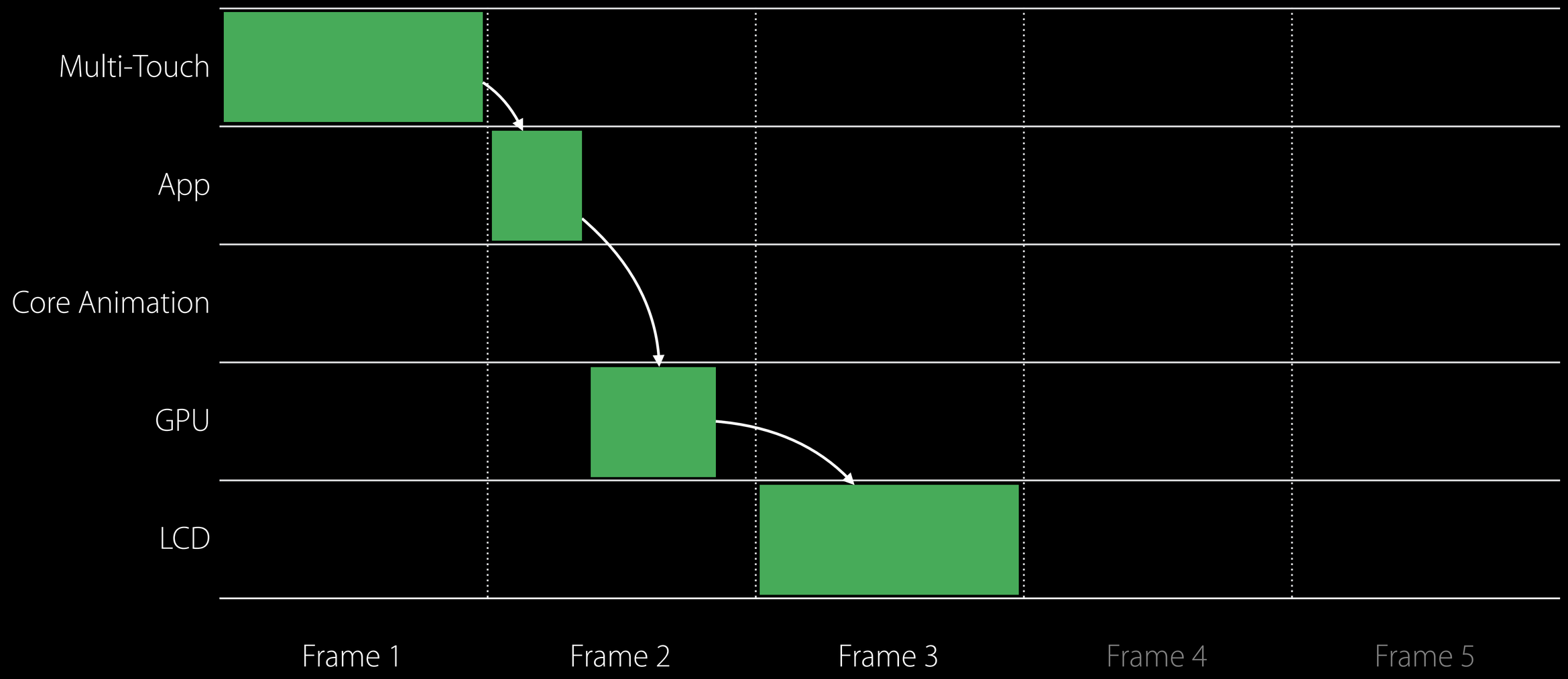
Metal and OpenGL

iOS 8



Metal and OpenGL

iOS 9



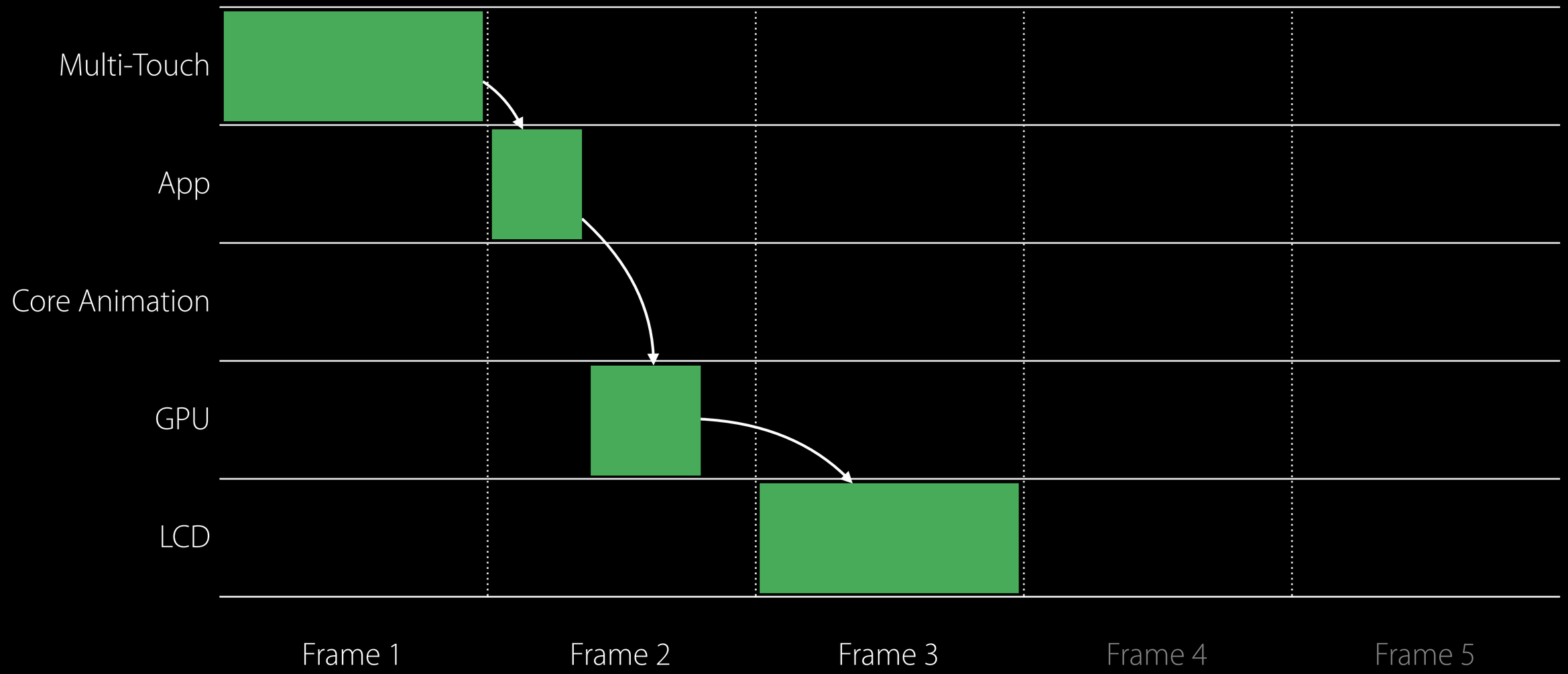
Low Latency Metal and OpenGL

CAEAGLLayer

CAMetalLayer

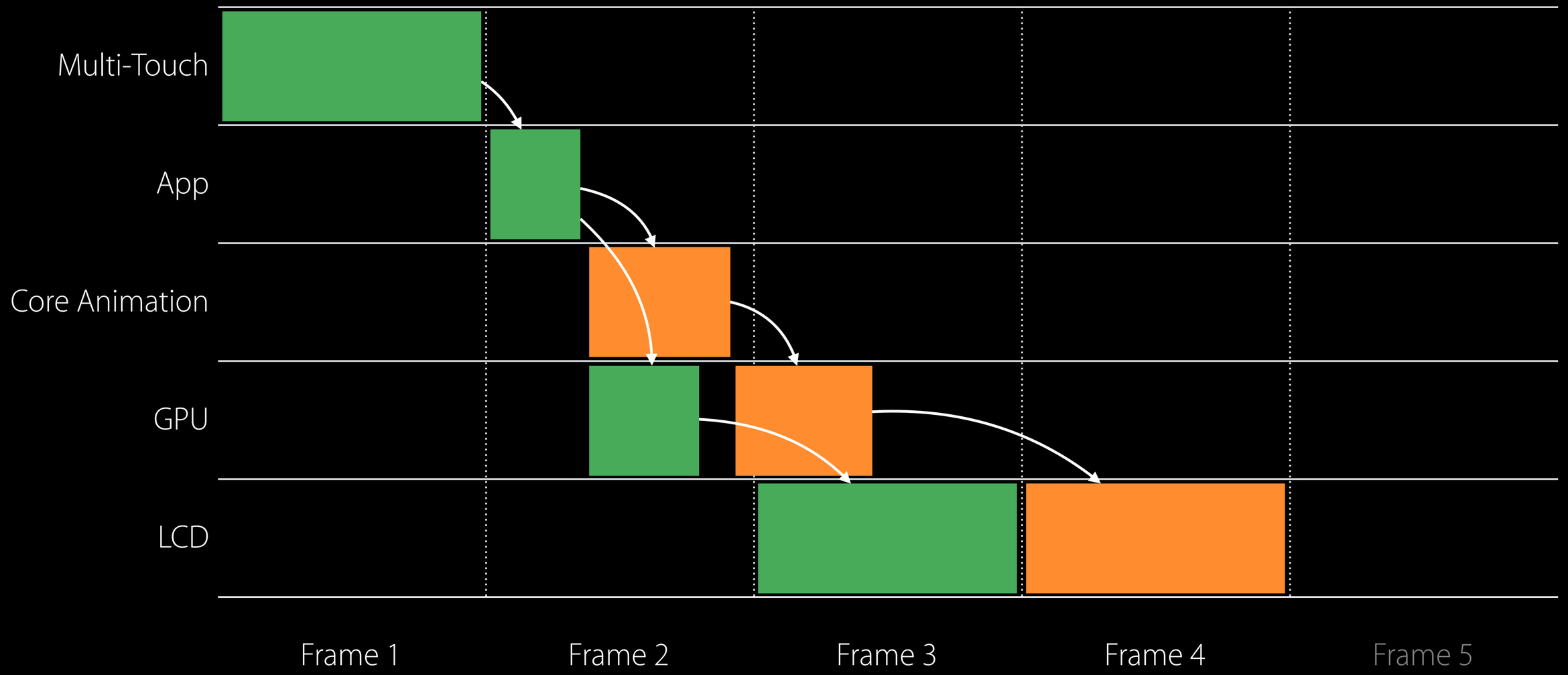
Low Latency Metal and OpenGL

With Core Animation



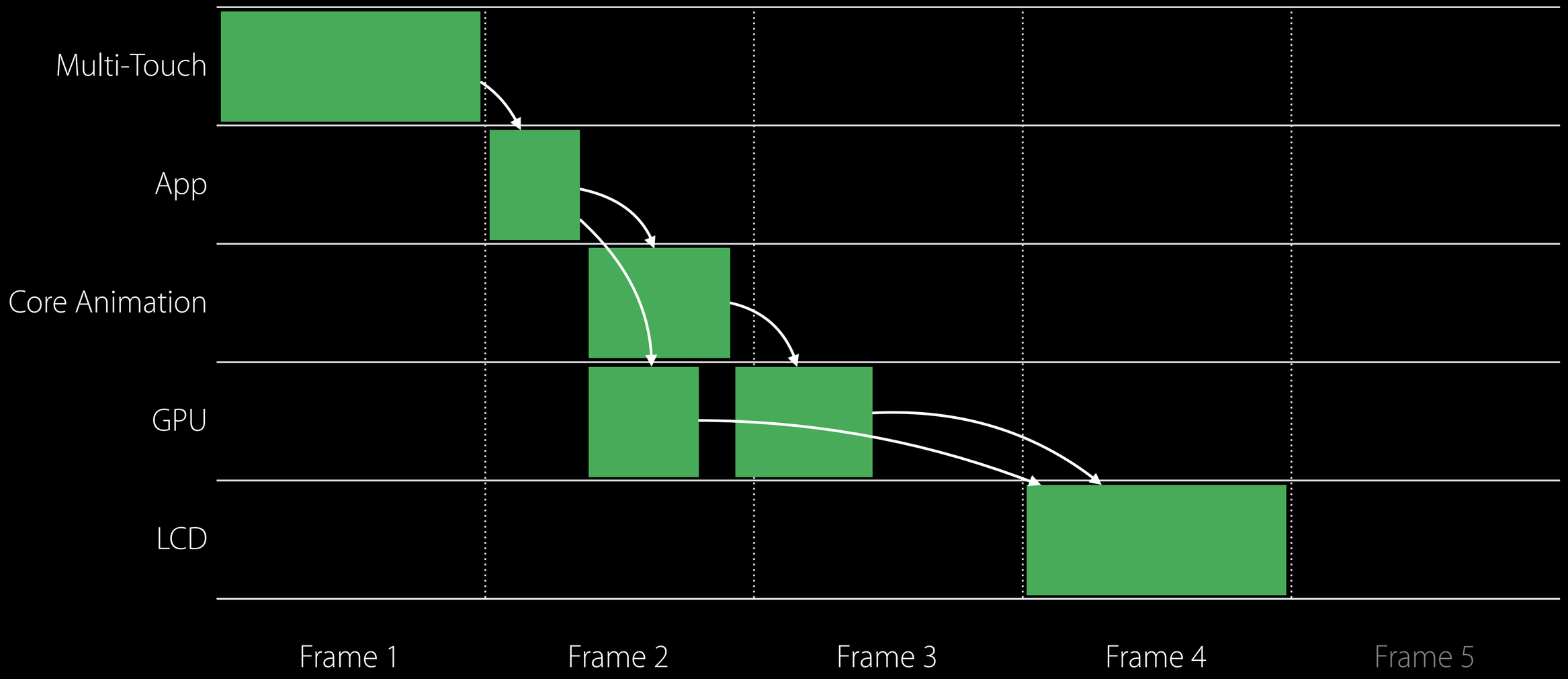
Low Latency Metal and OpenGL

With Core Animation



Low Latency Metal and OpenGL

With Core Animation



Low Latency Metal and OpenGL

CAEAGLLayer and CAMetalLayer

```
// For lowest latency (default):
layer.presentsWithTransaction = false
```

Low Latency Metal and OpenGL

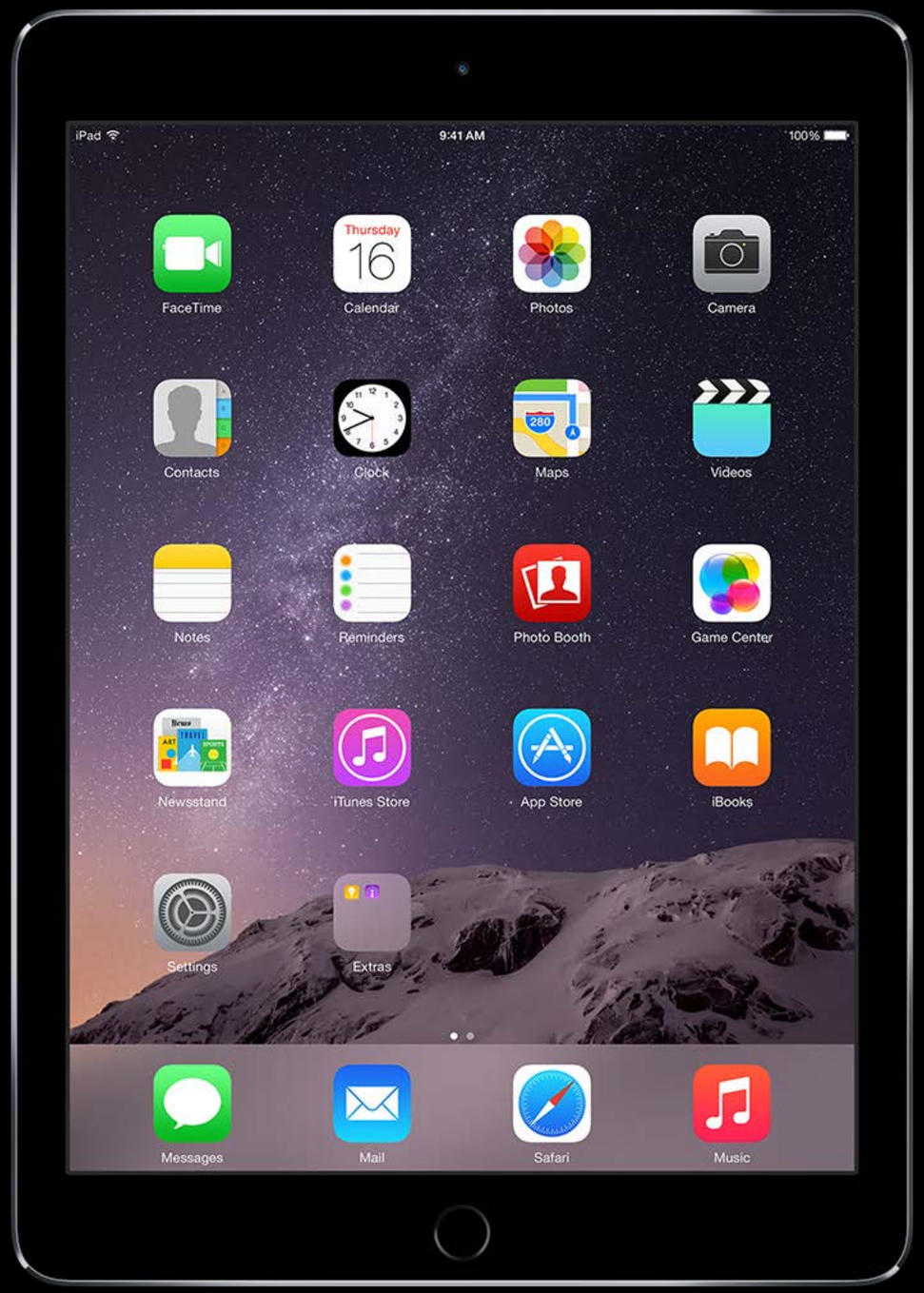
CAEAGLLayer and CAMetalLayer

```
// For lowest latency (default):
layer.presentsWithTransaction = false

// For synchronizing with CA:
layer.presentsWithTransaction = true
```

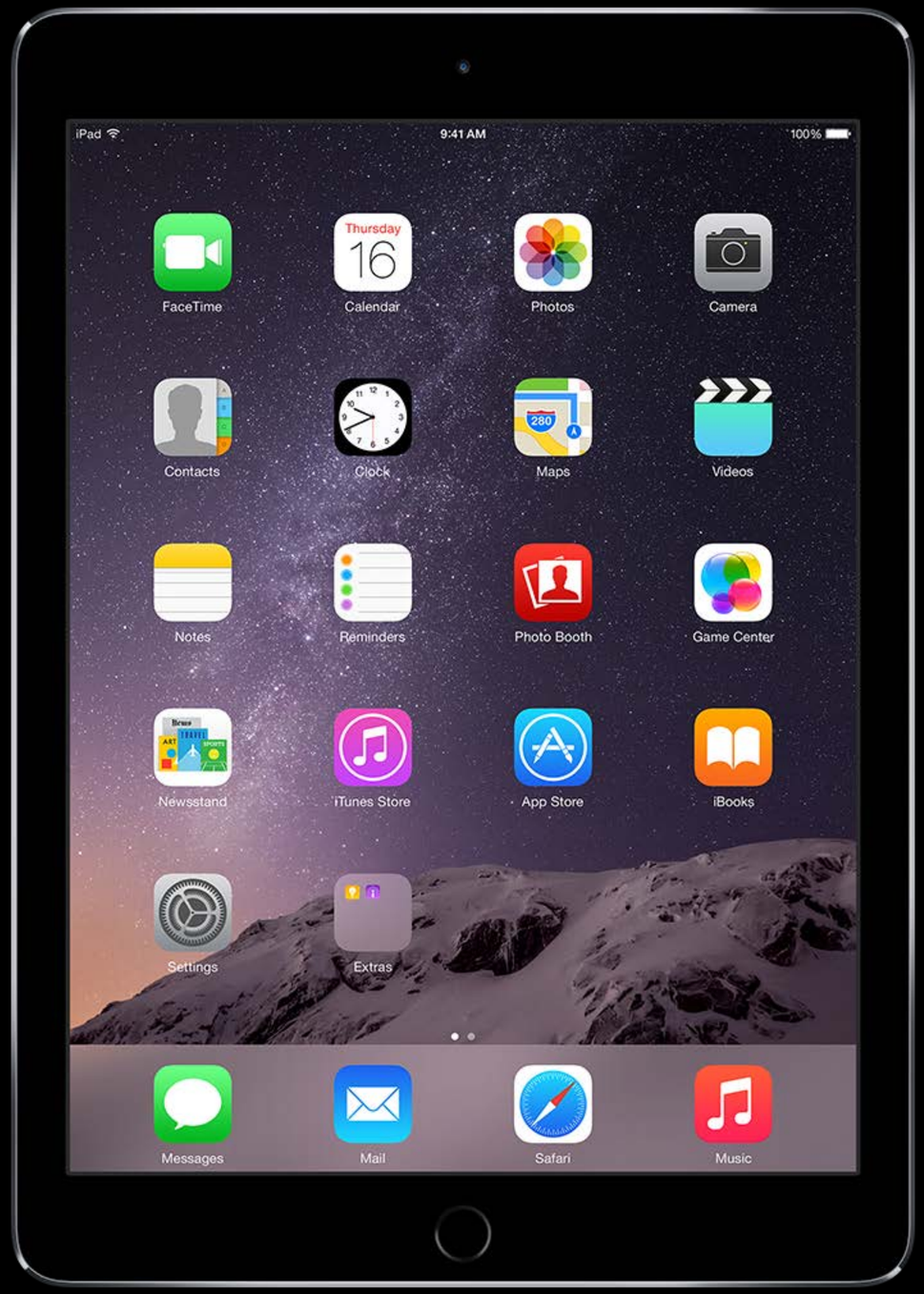
Touch Coalescing

iPad Air 2


iPad
9:41 AM
100%
FaceTime
Thursday
16
Calendar
Photos
Camera
Contacts
Clock
280
Maps
Videos
Notes
Reminders
Photo Booth
Game Center
Newsstand
iTunes Store
App Store
iBooks
Settings
Extras
Messages
Mail
Safari
Music

iPad Air 2

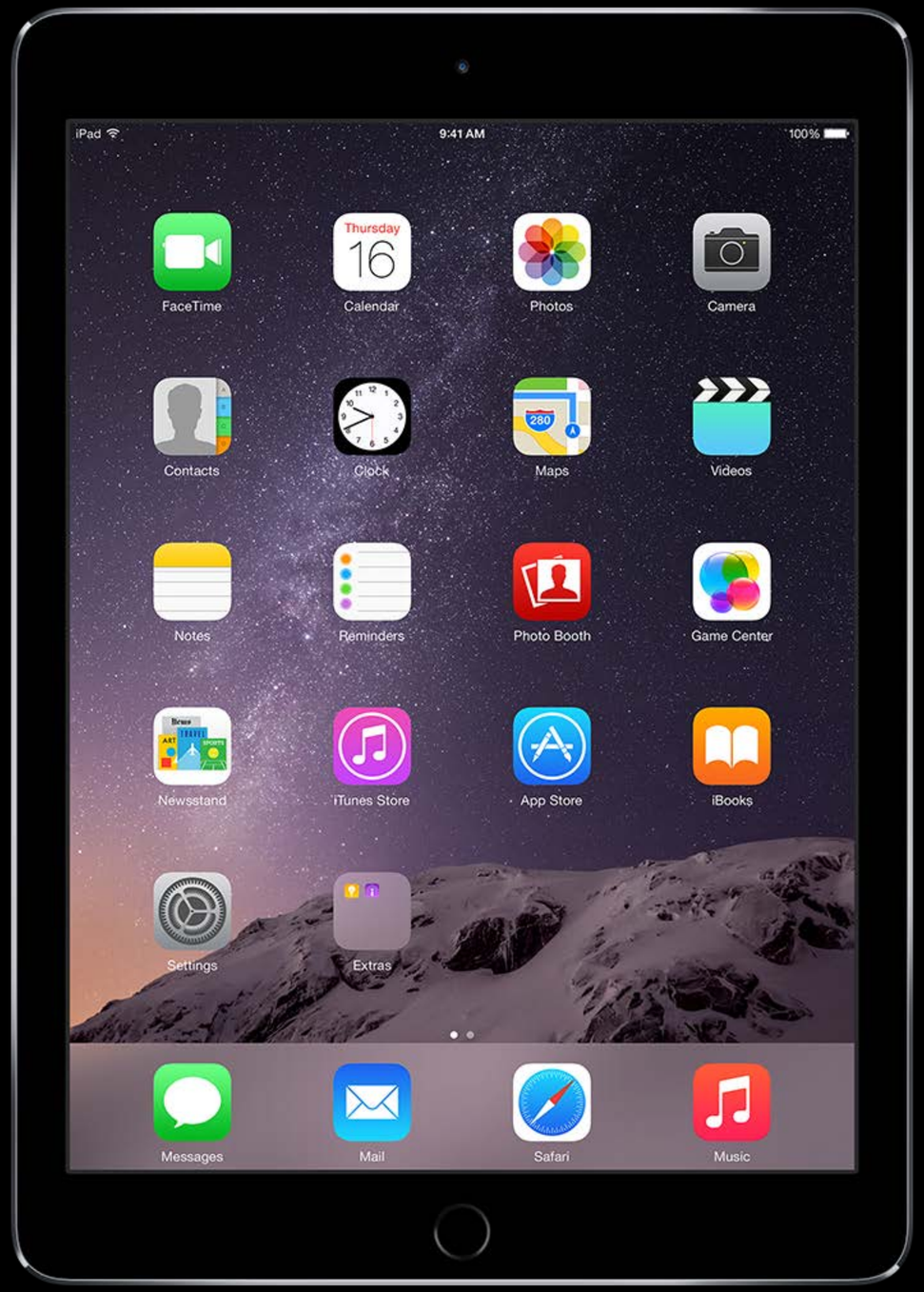
60 Hz Display Update



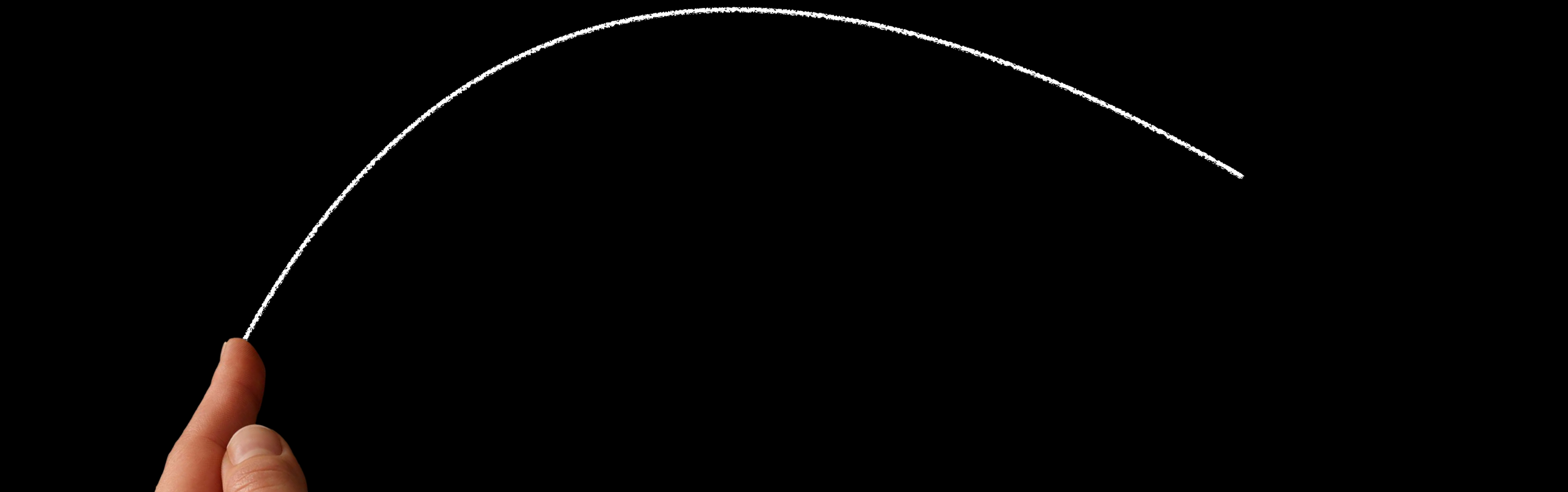
iPad Air 2

60 Hz Display Update

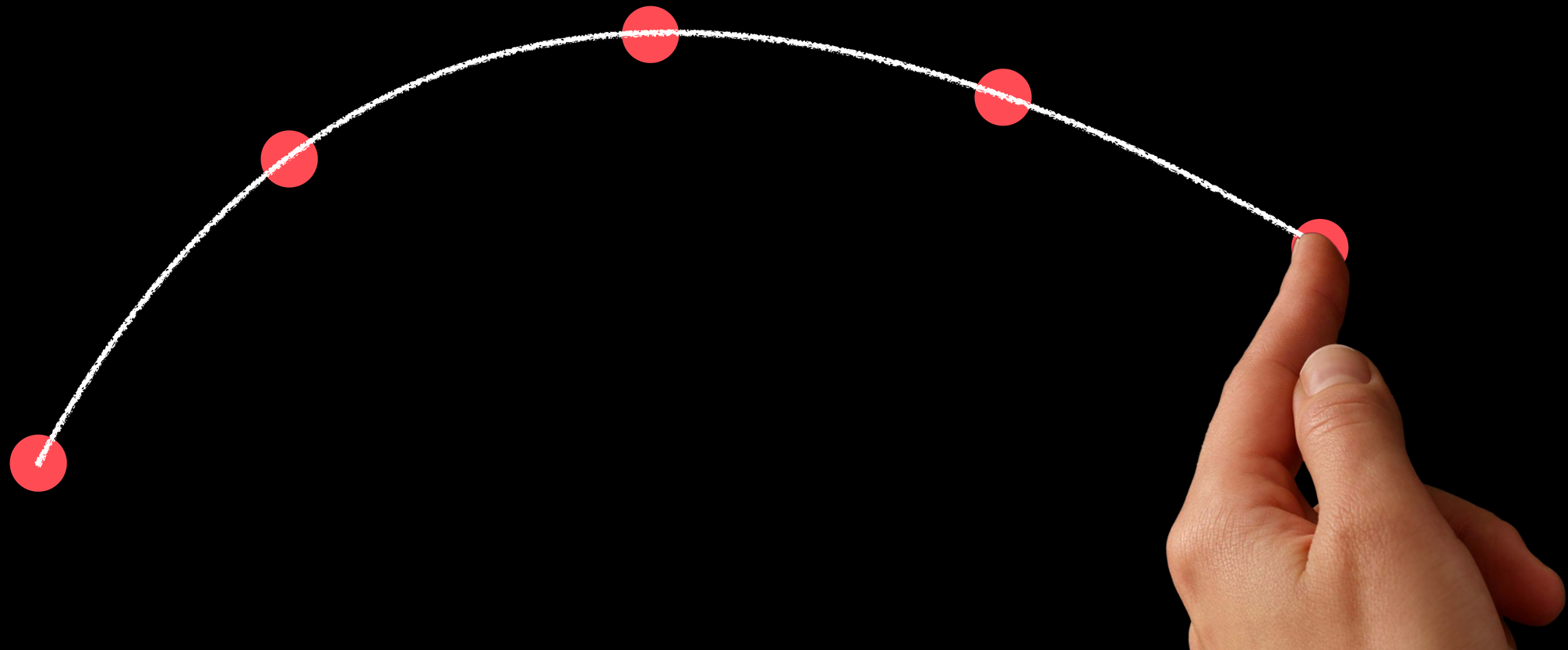
120 Hz Touch Scan



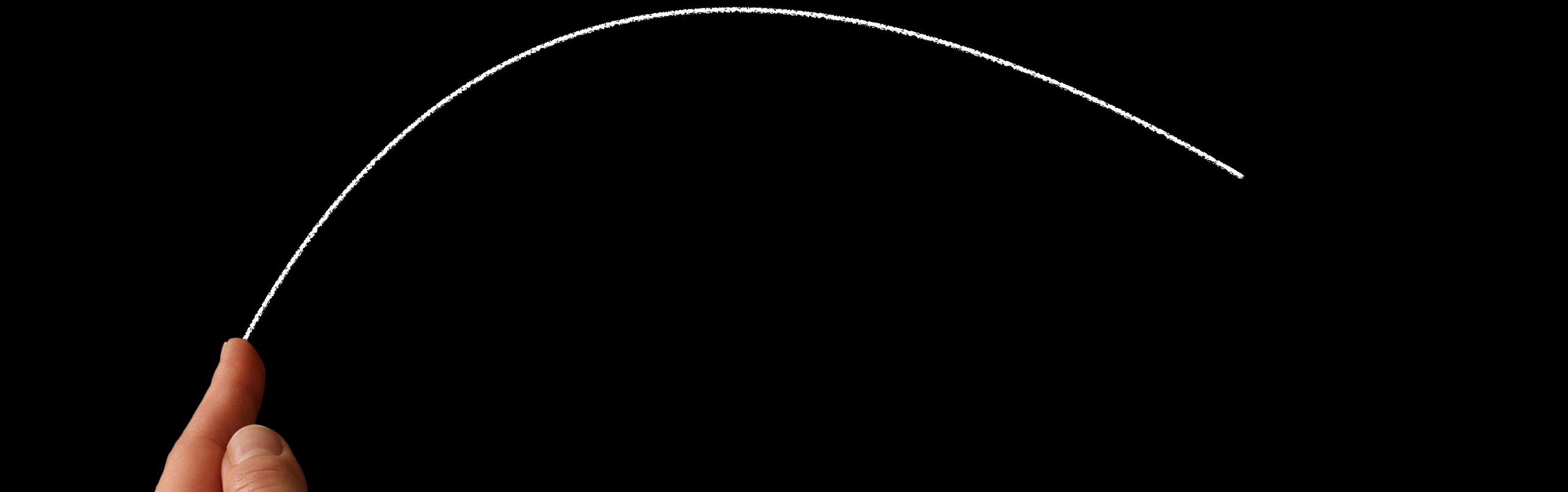
60 Hz Touch Scan



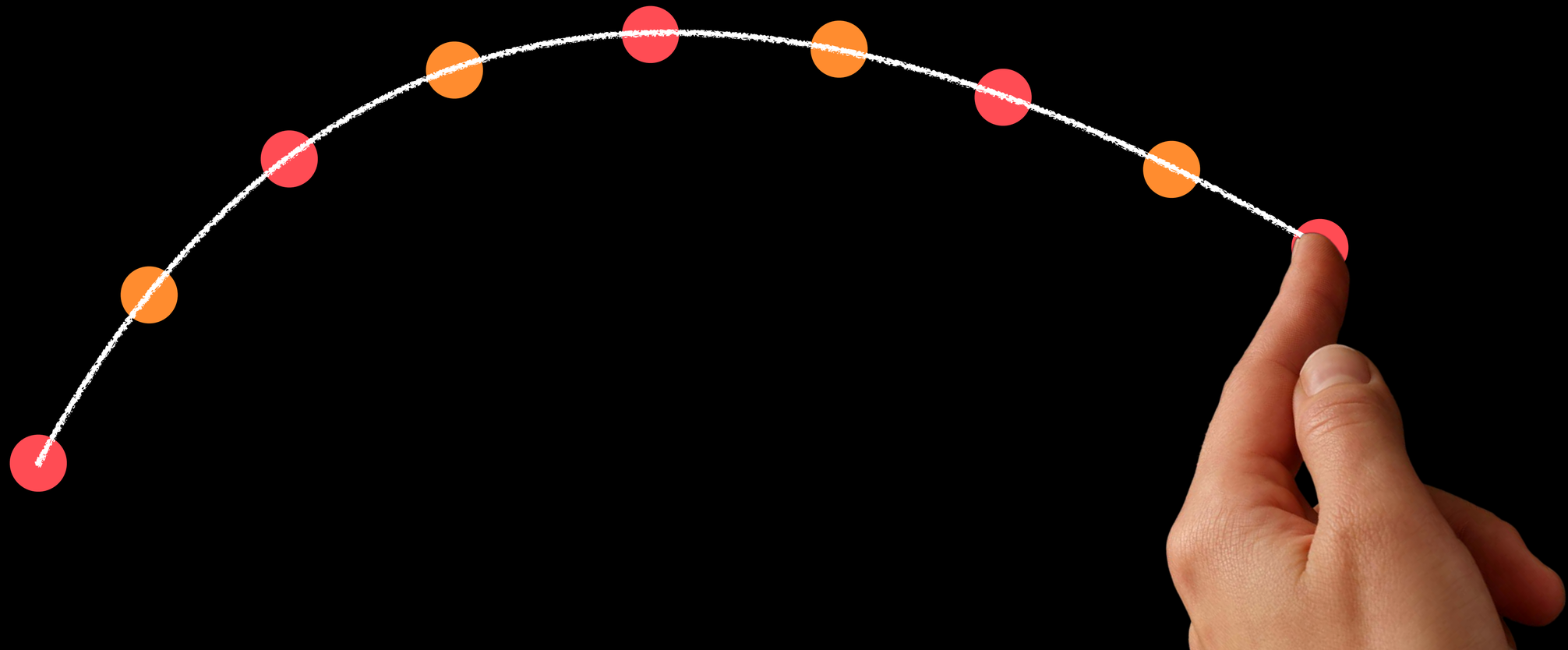
60 Hz Touch Scan



120 Hz Touch Scan



120 Hz Touch Scan



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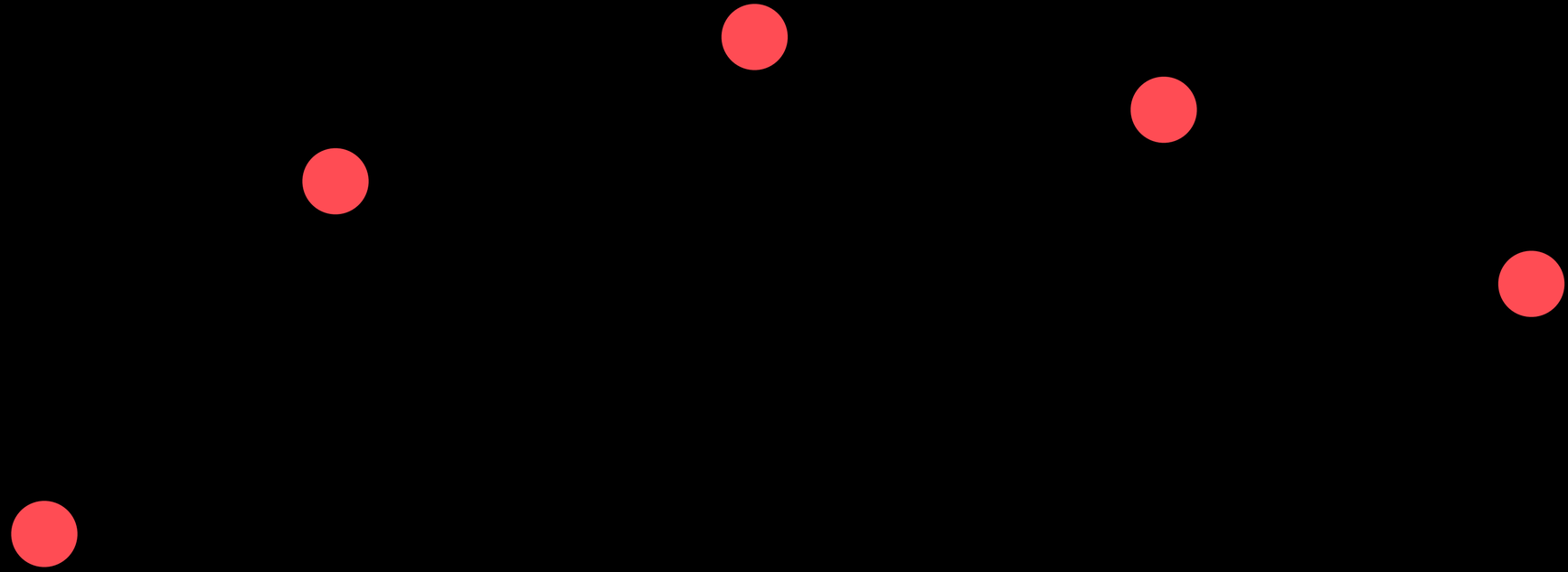

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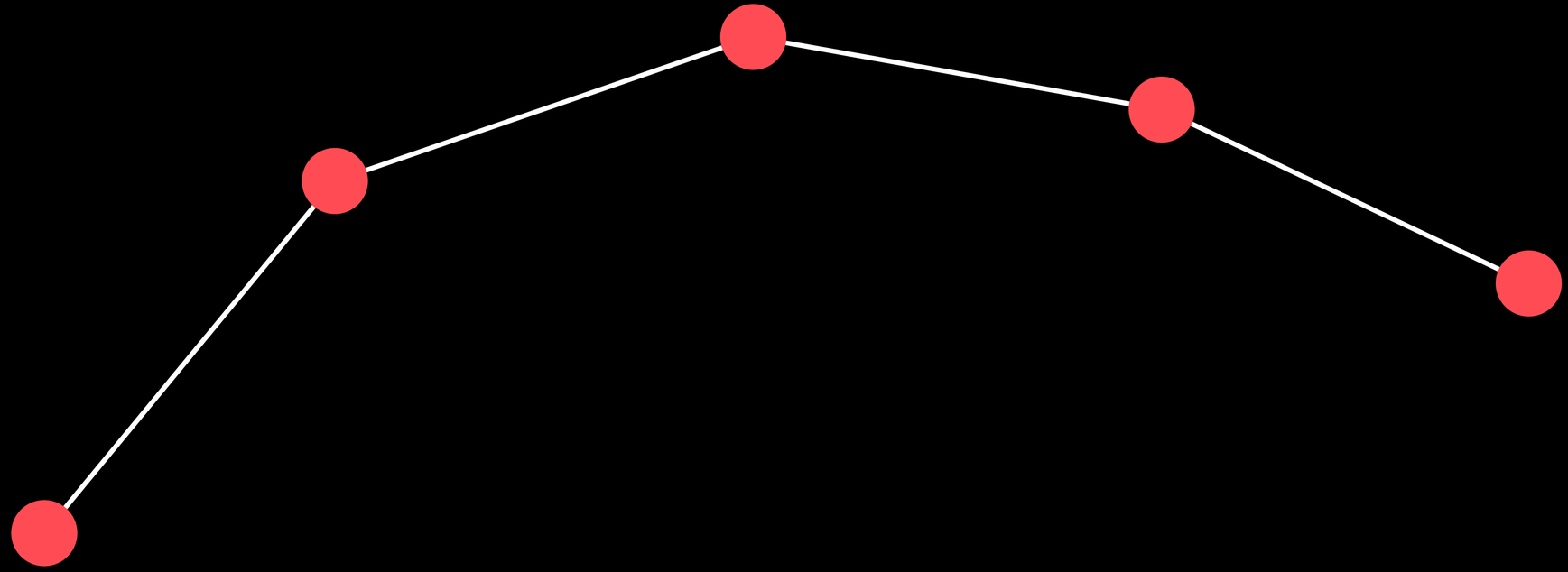

120 Hz Touch Scan

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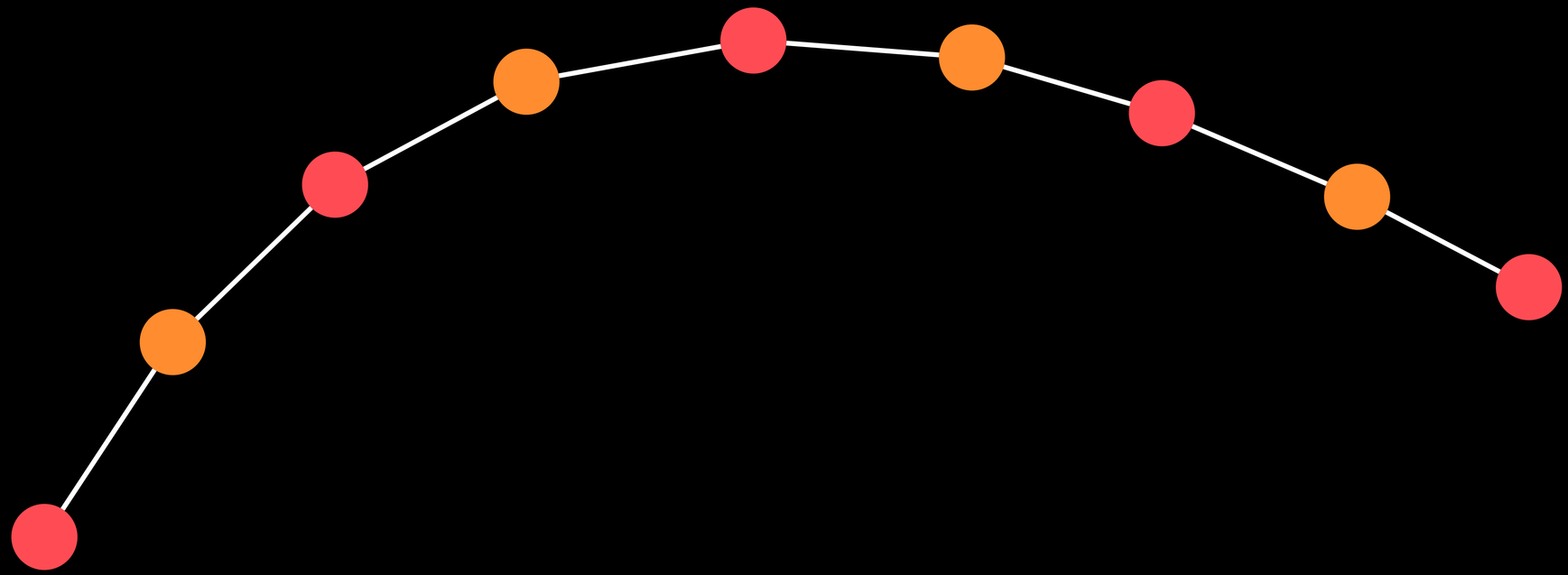

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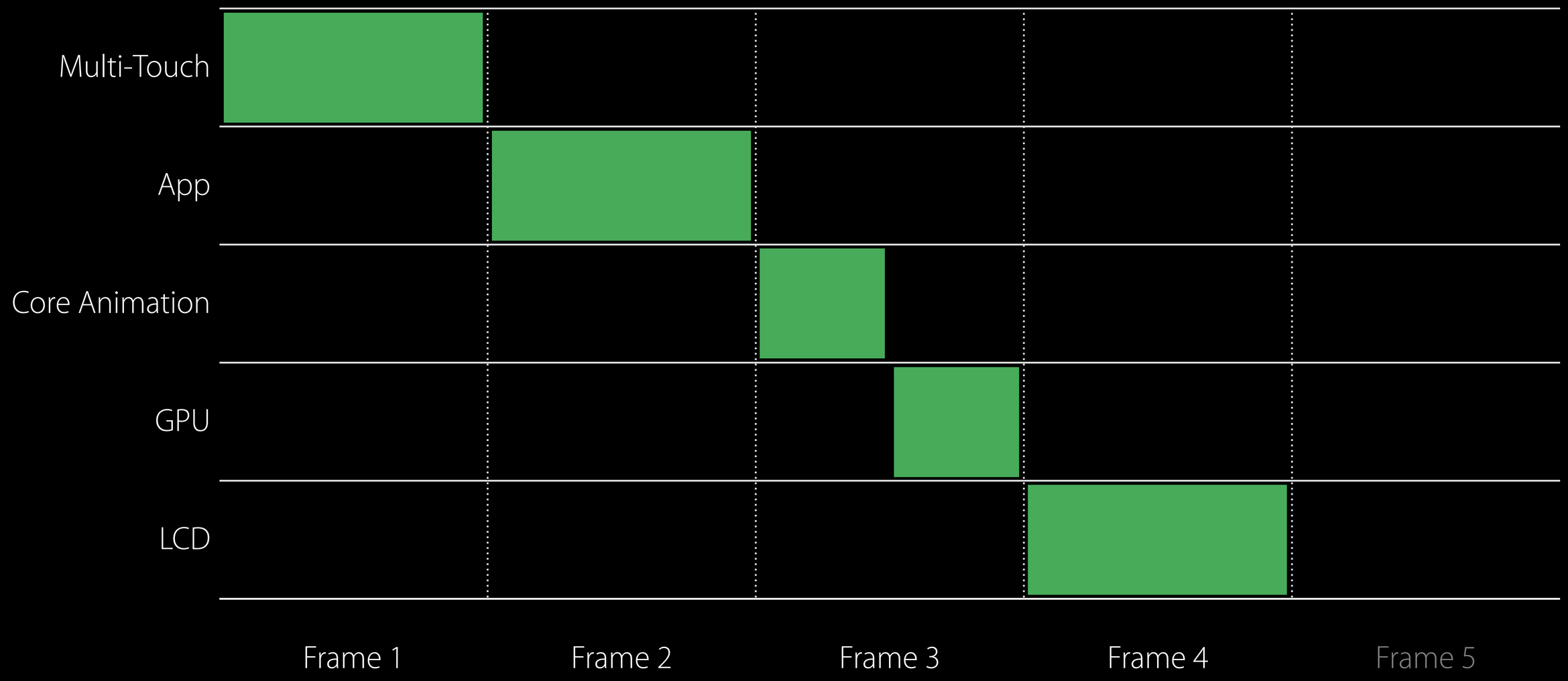

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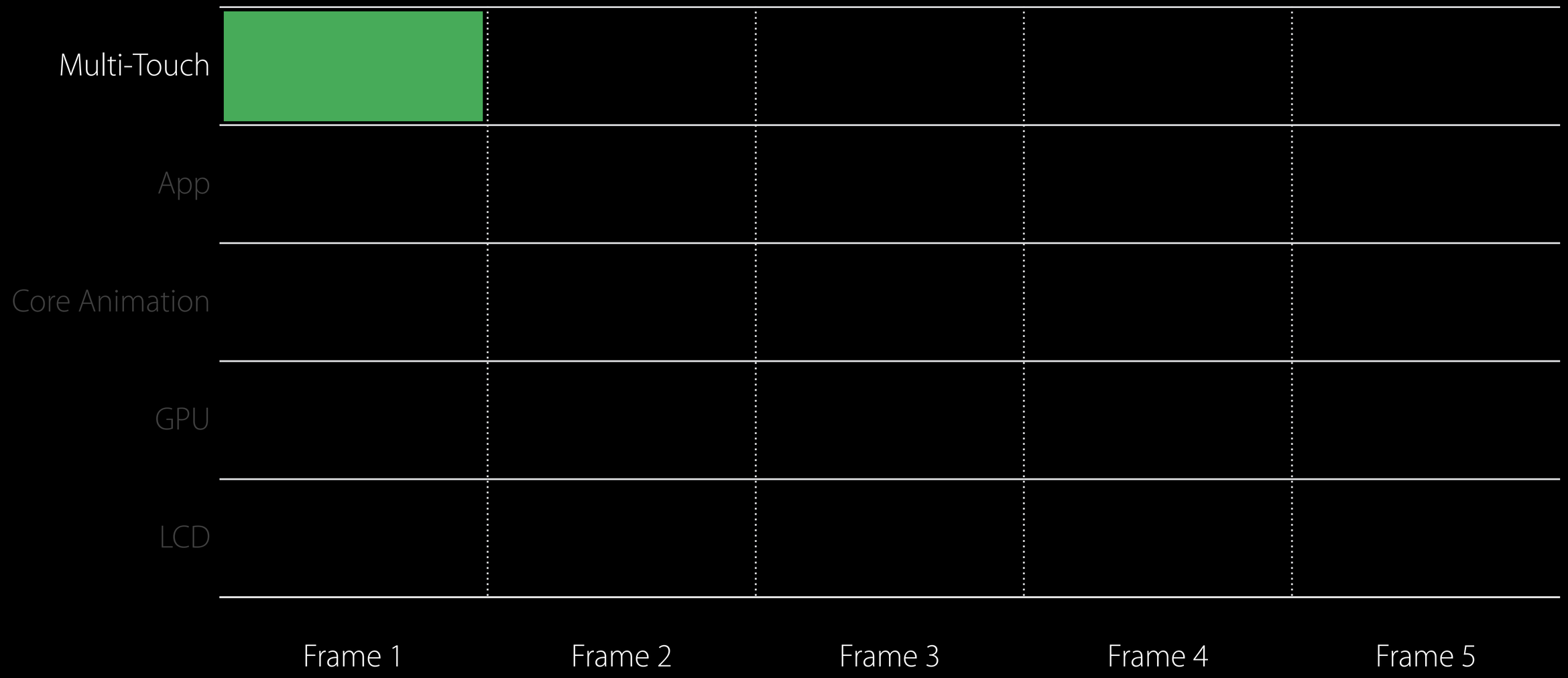

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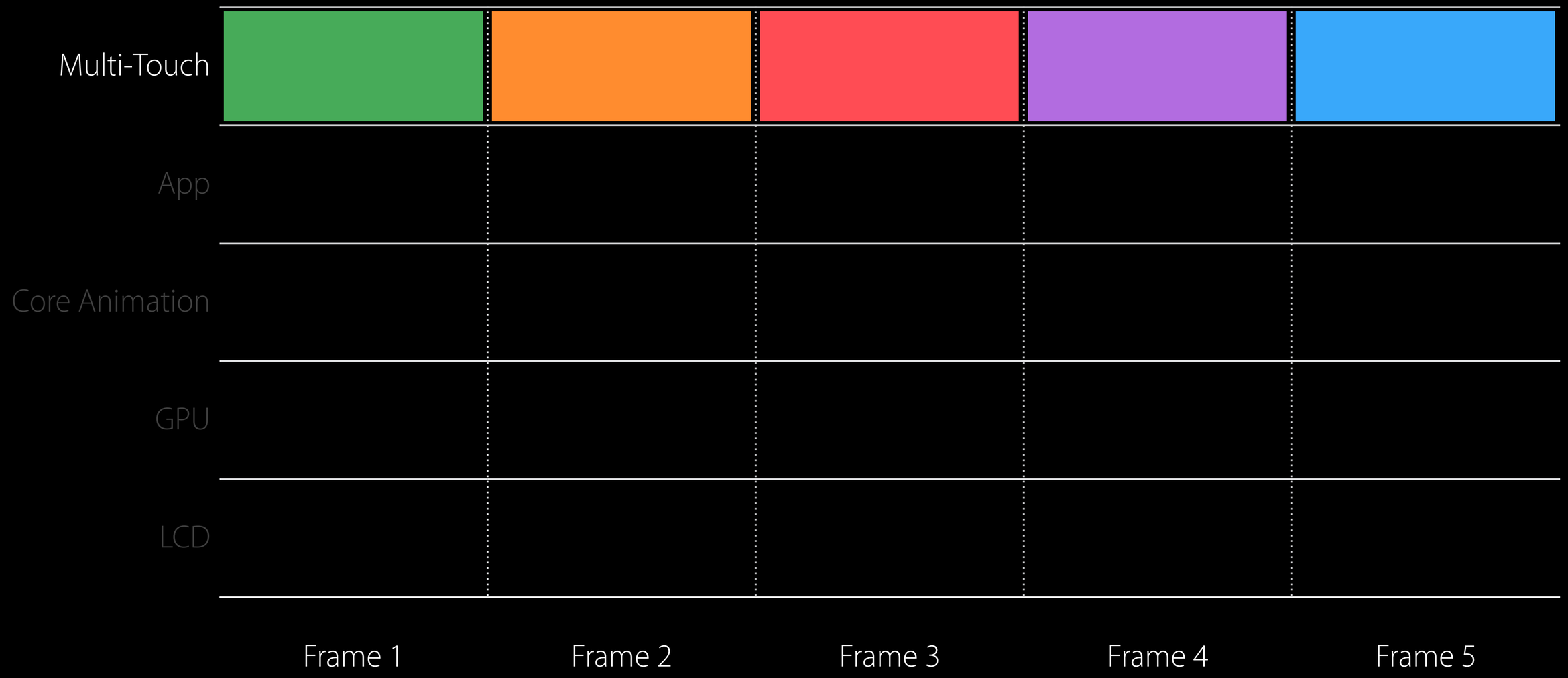

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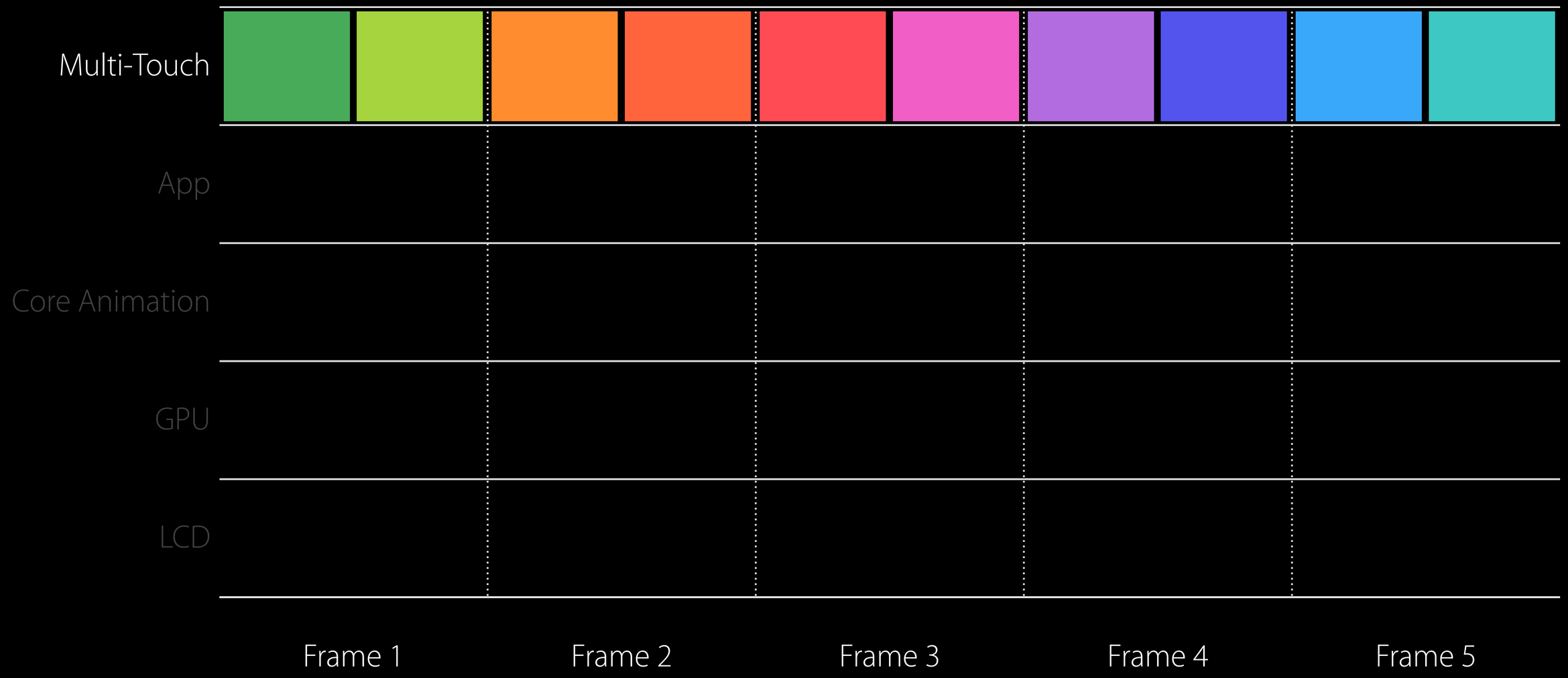

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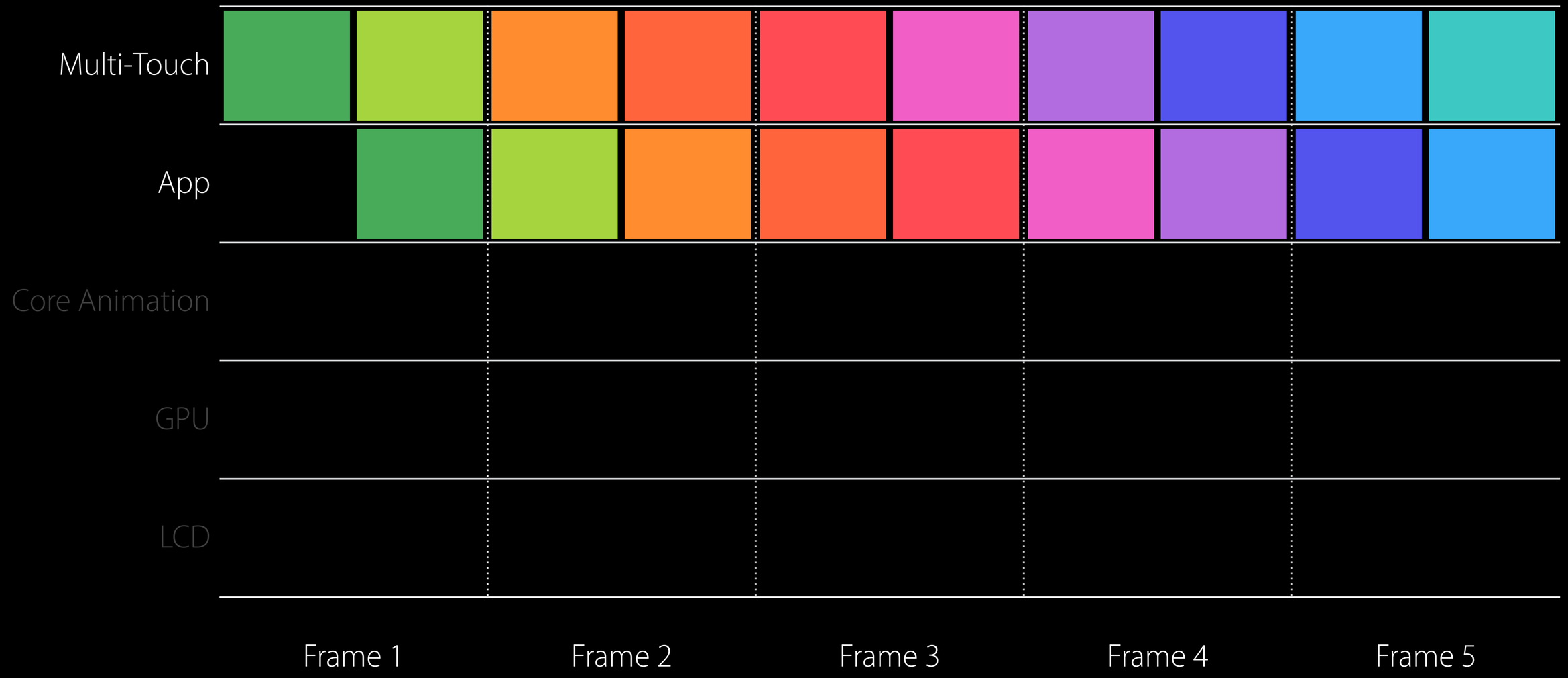

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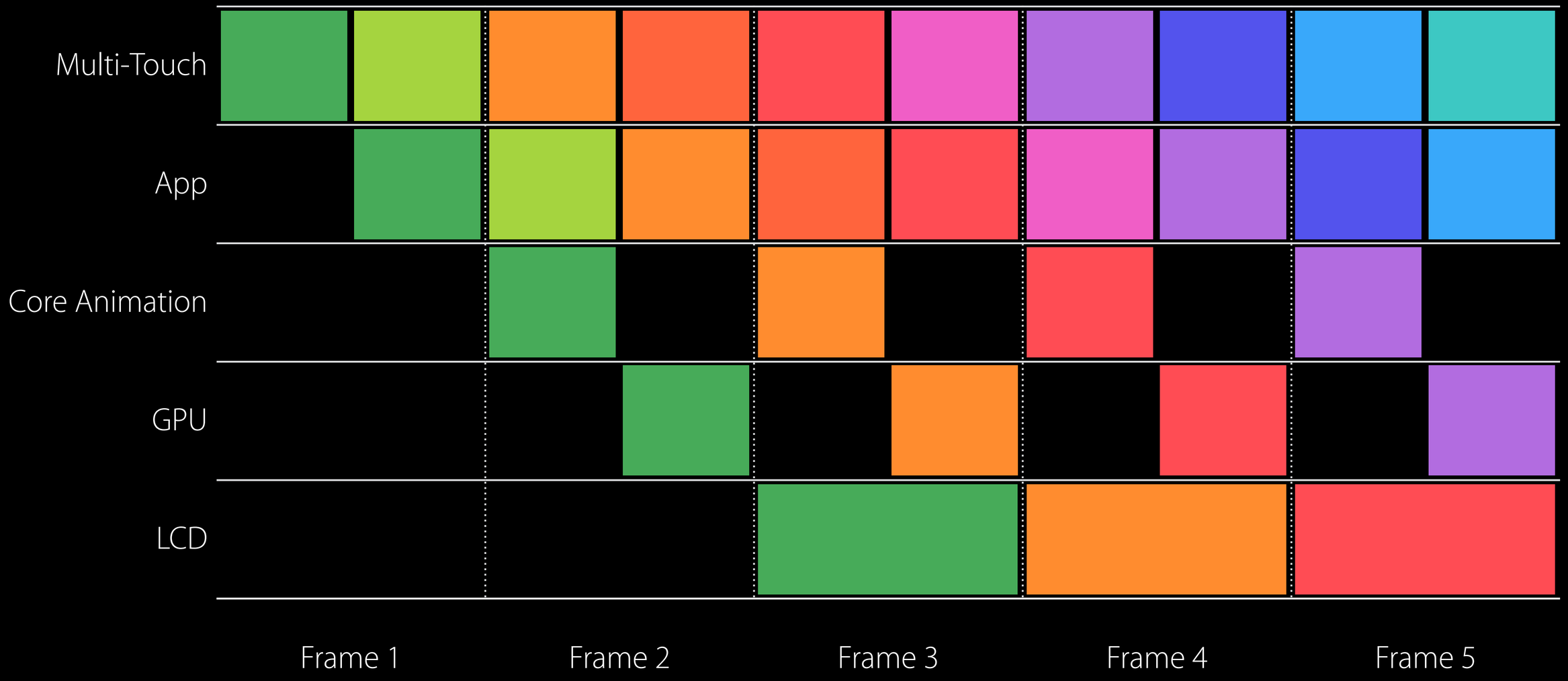
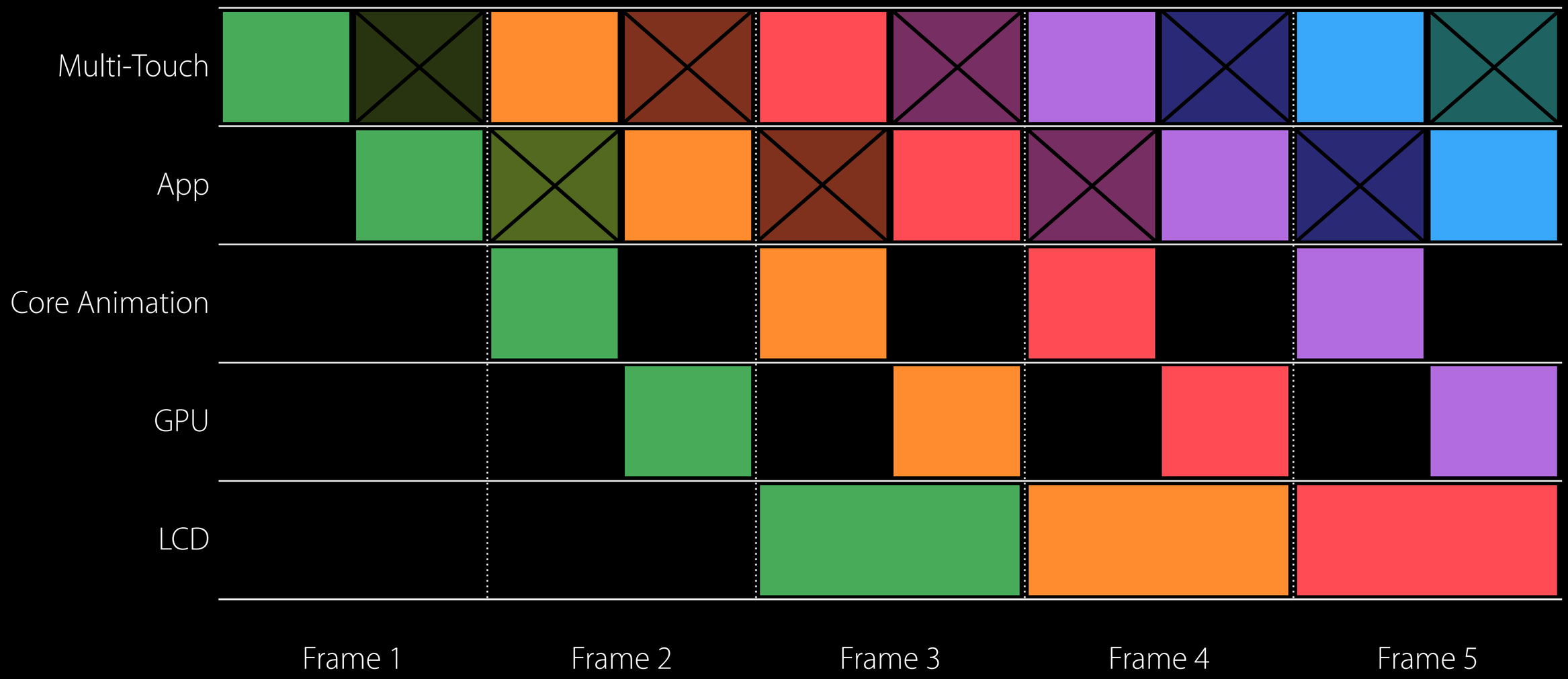
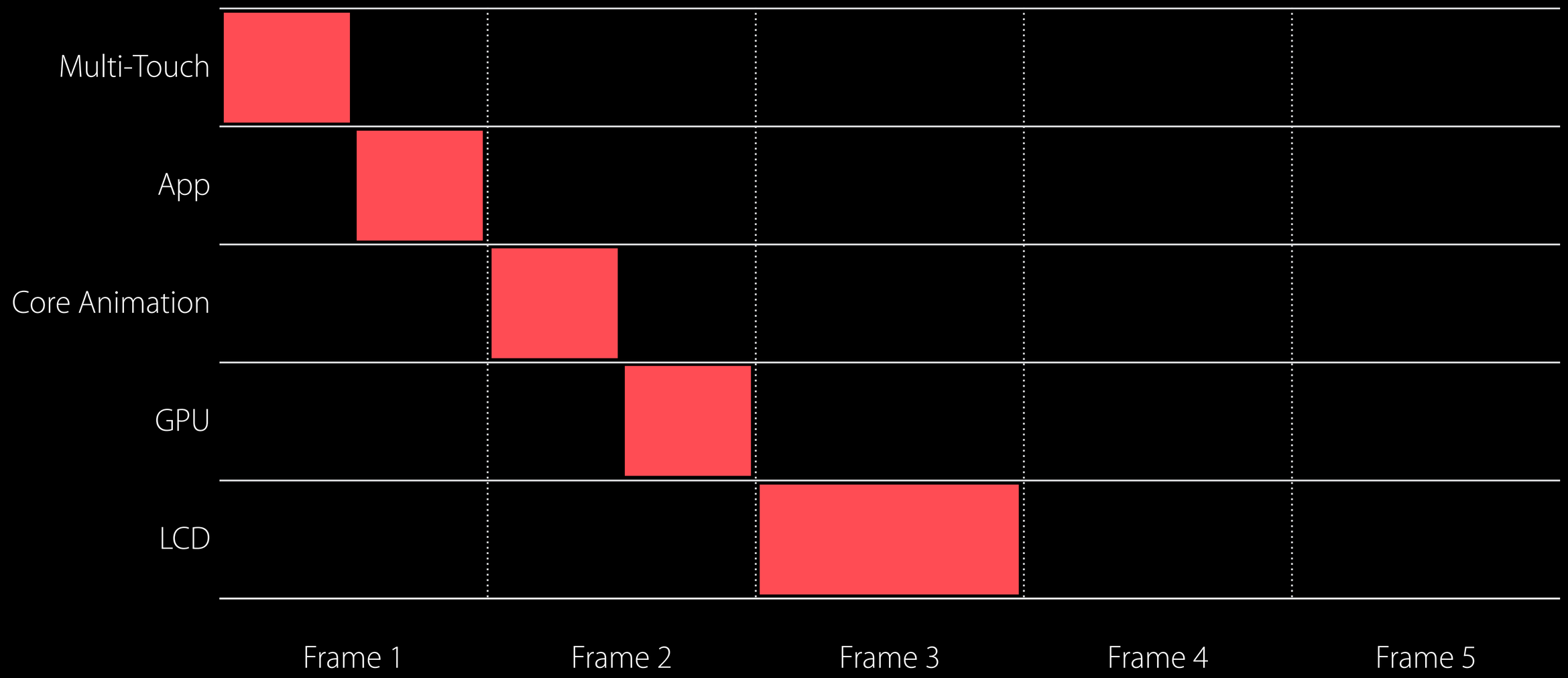


120 Hz Touch Scan



120 Hz Coalesced



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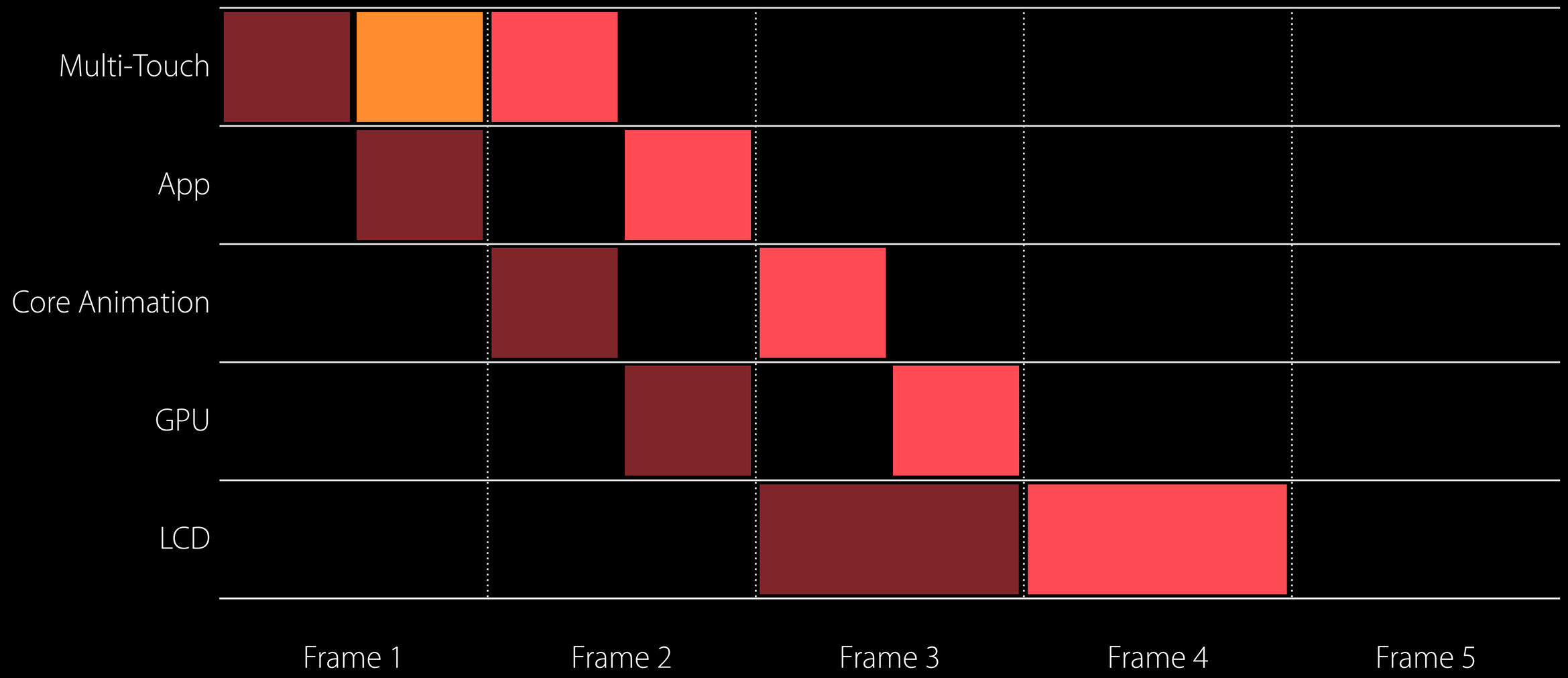
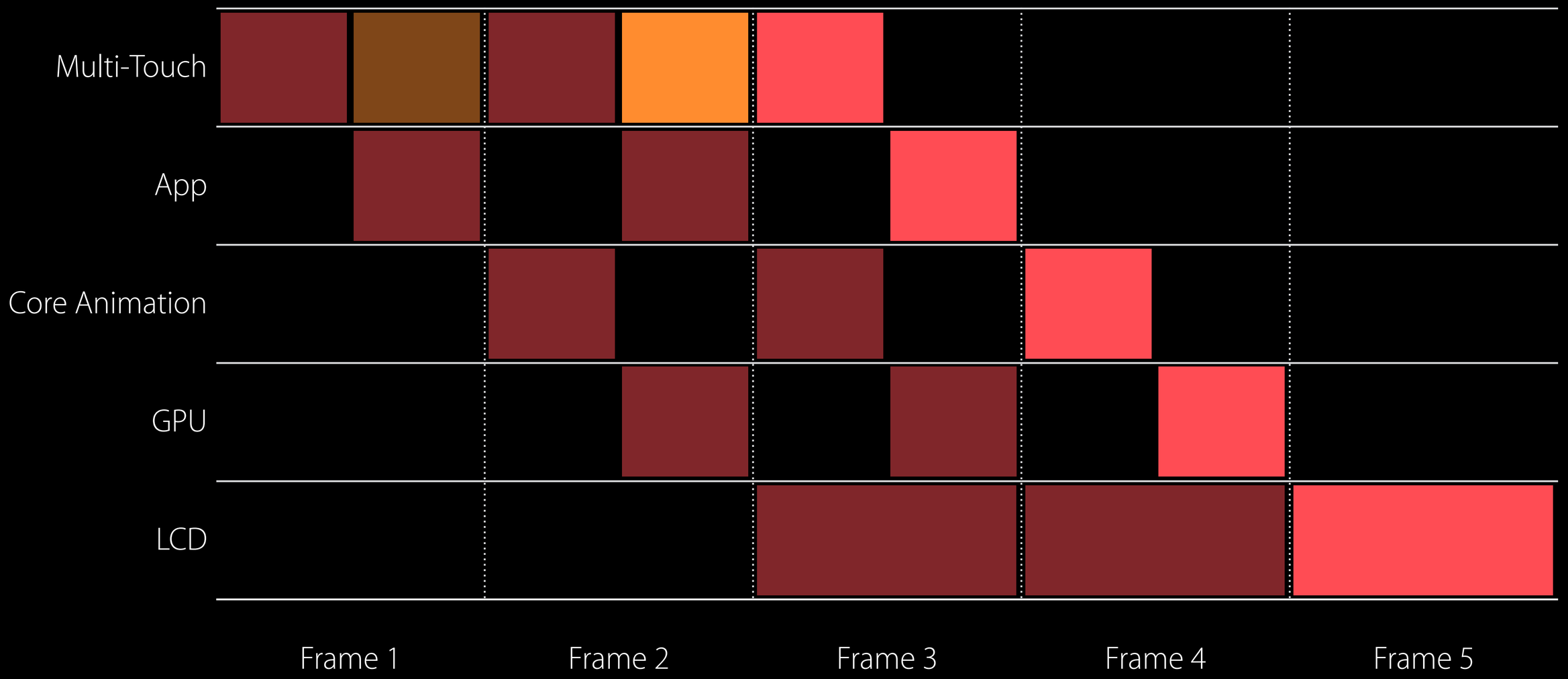
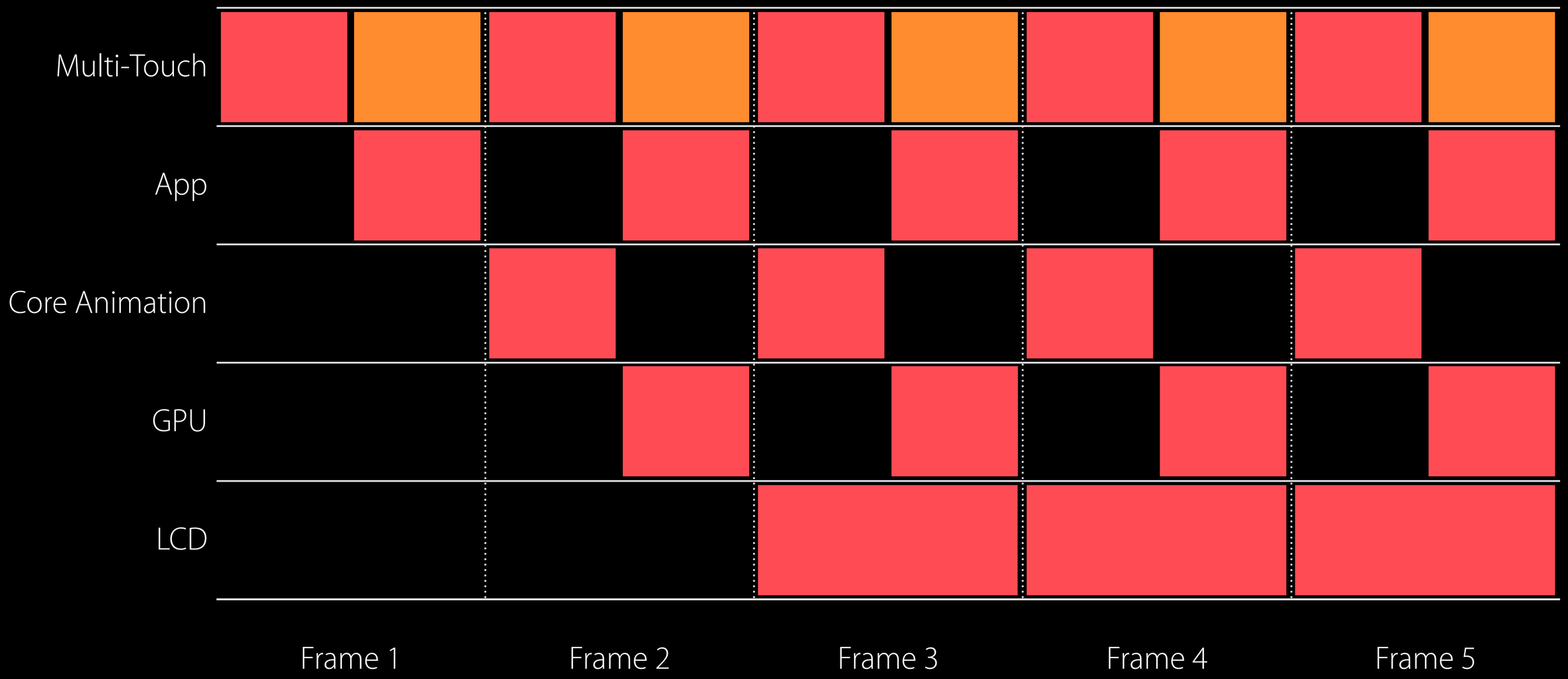


120 Hz Coalesced



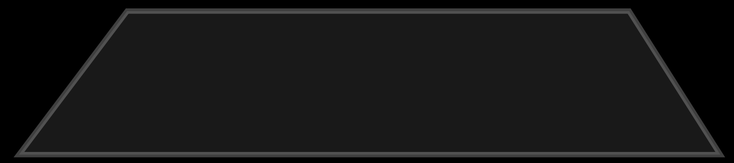
120 Hz Coalesced



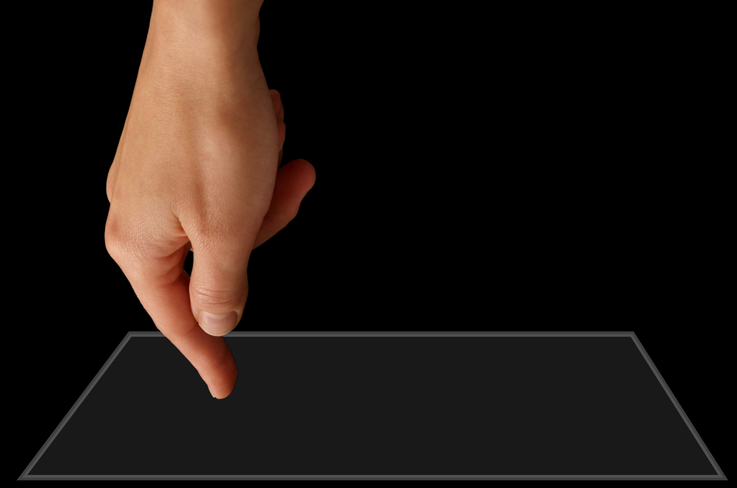
Touch Coalescing

```
UIEvent.coalescedTouchesForTouch(touch: UITouch)
    -> [UITouch]?
```

Touch Sequence

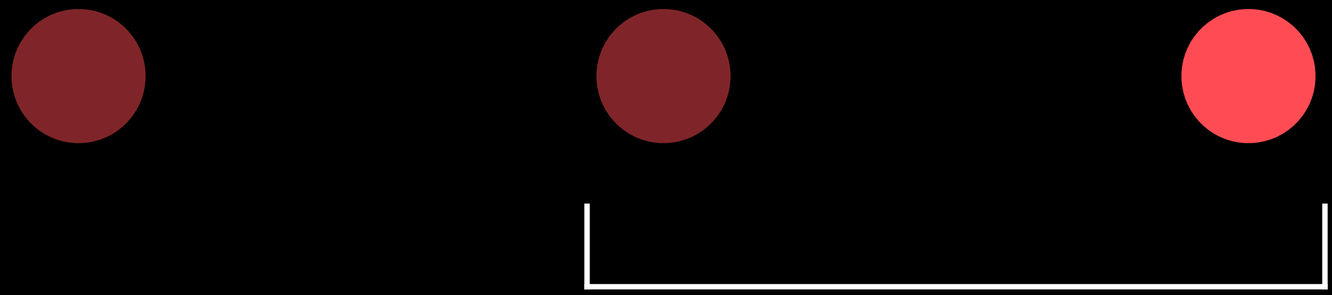


Touch Sequence



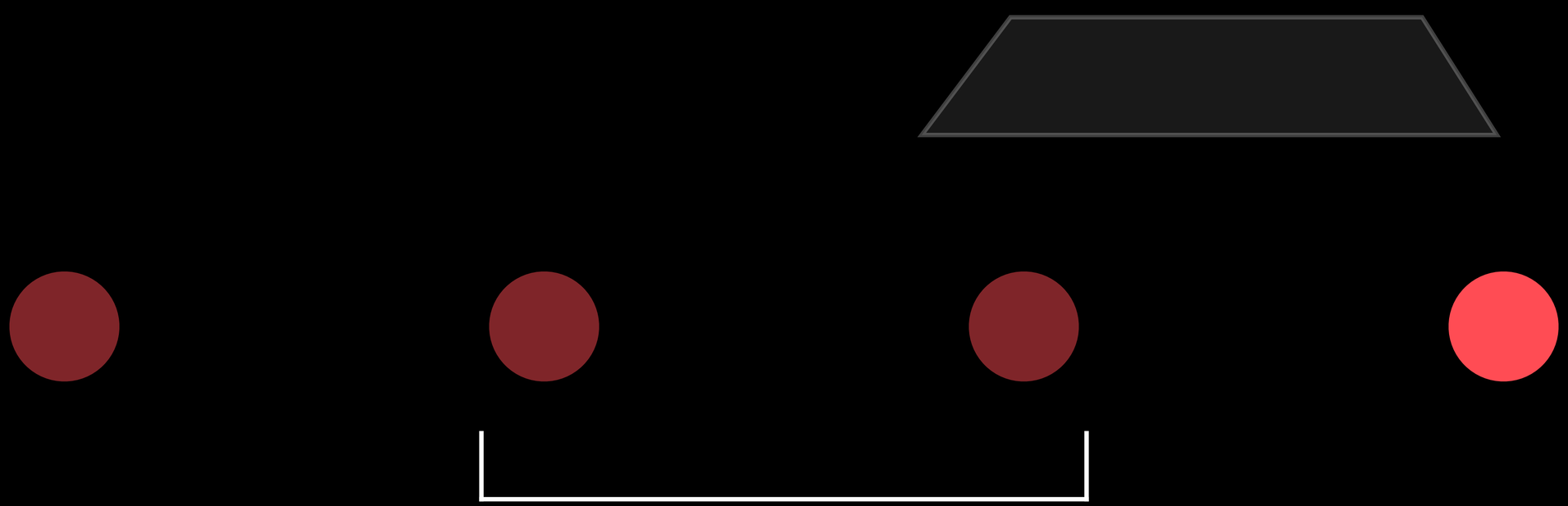
```
touchesBegan
```

Touch Sequence

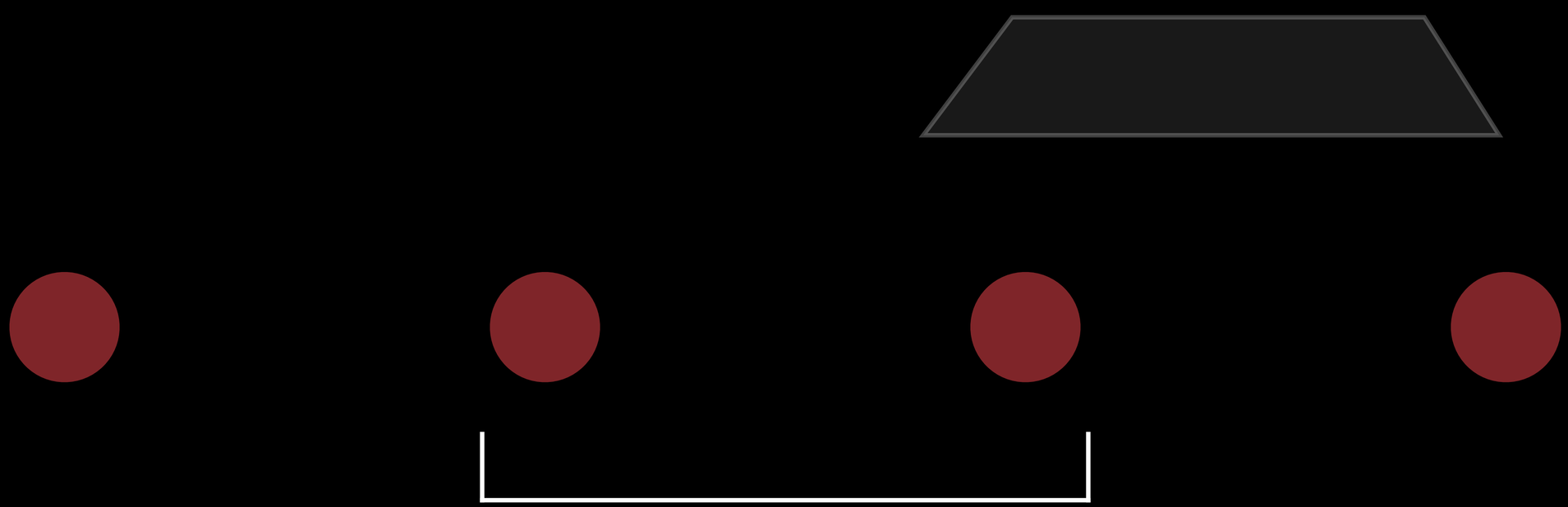


touchesBegan touchesMoved

Touch Sequence



Touch Sequence



touchesBegan

touchesMoved

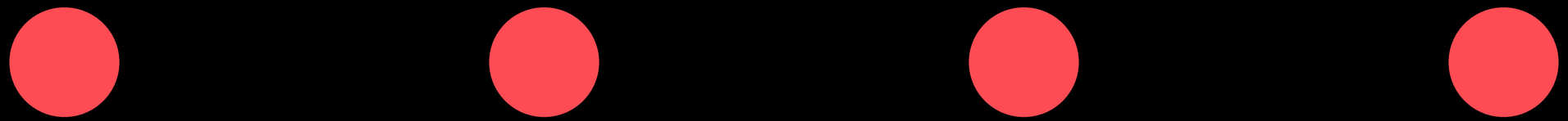
touchesEnded

touchesCancelled

Touch Sequence

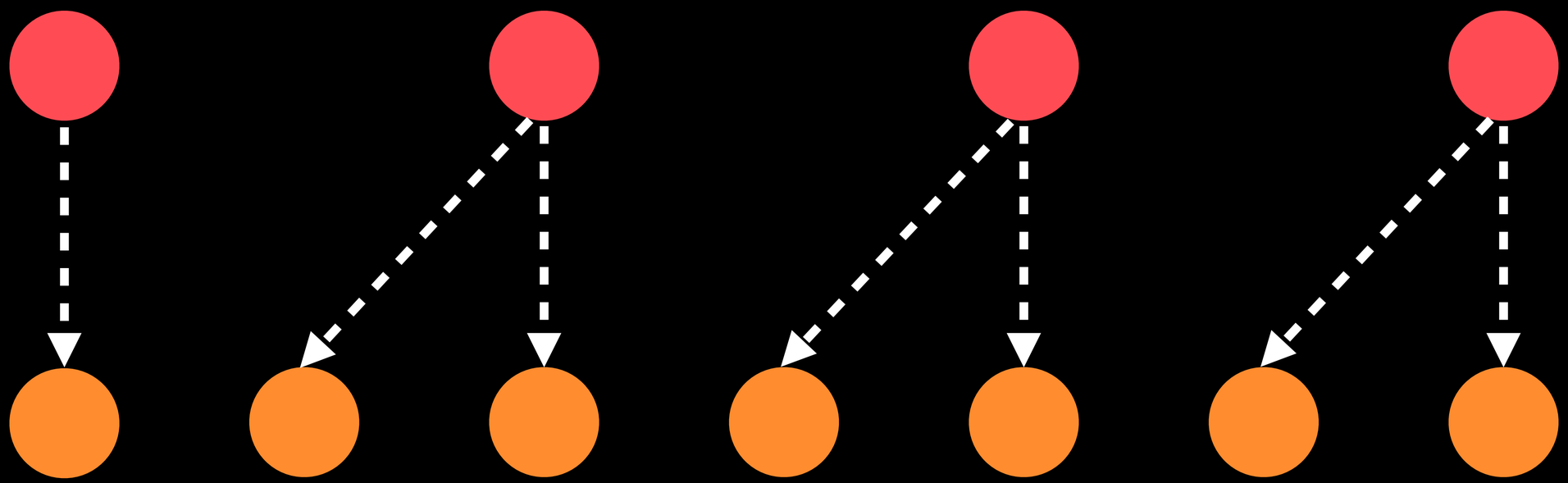
```
----▶ coalescedTouchesForTouch
```

Main Touches

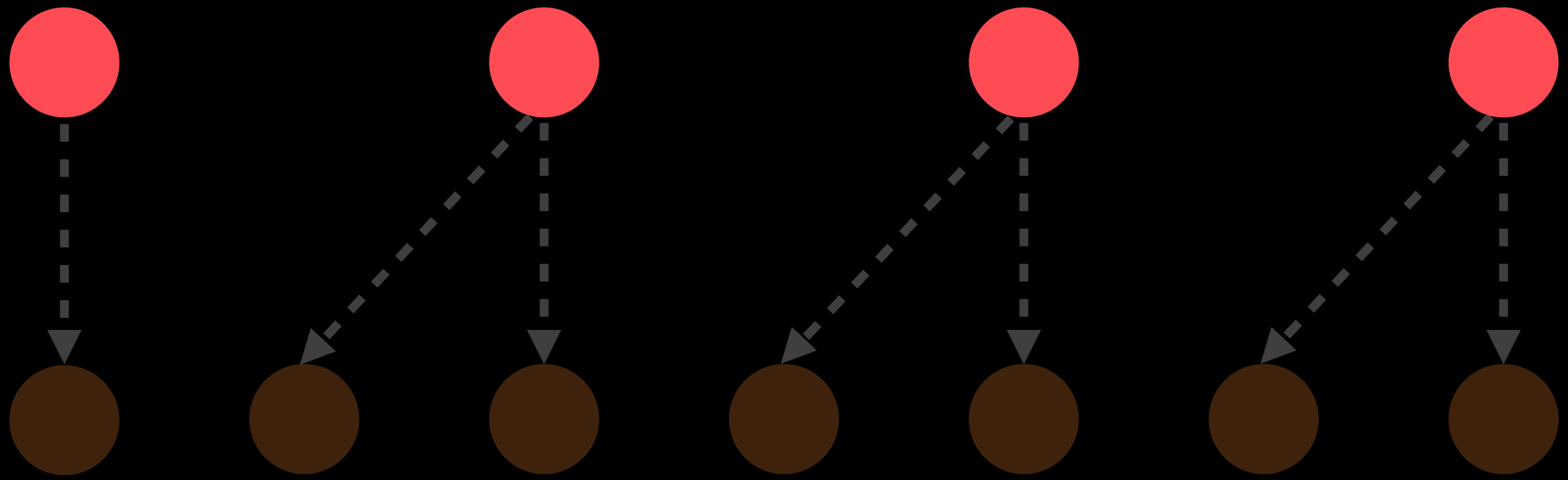


Touch Sequence

`----▸` `coalescedTouchesForTouch`



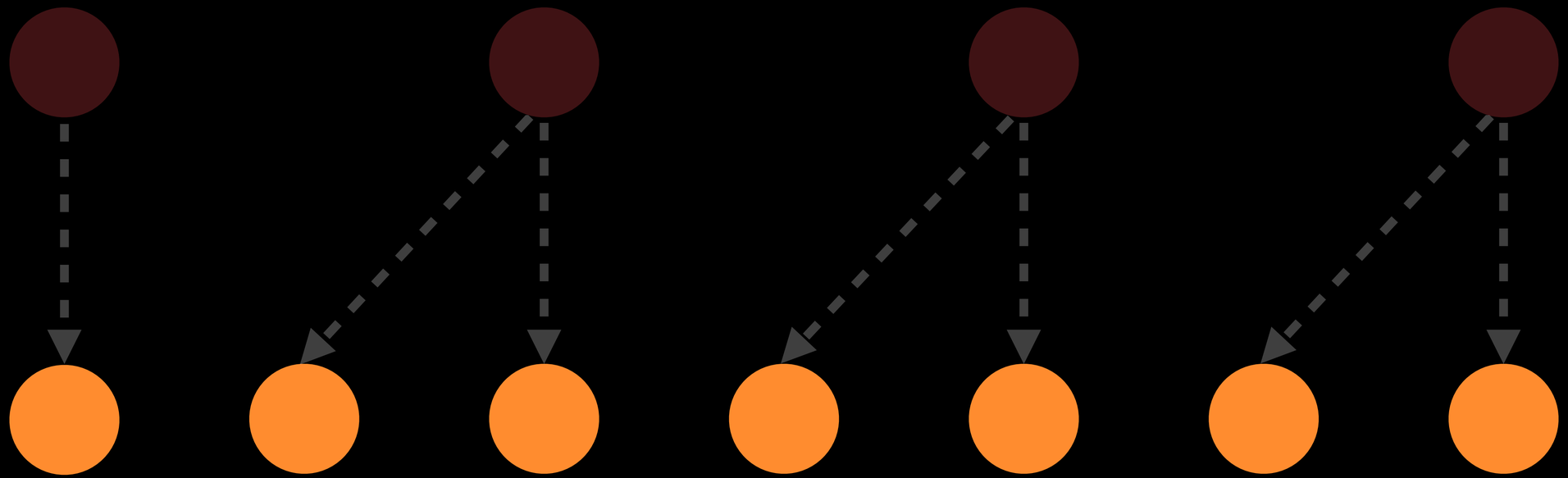
Touch Sequence



Touch Sequence

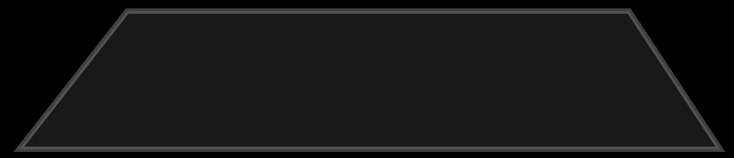
----▸ coalescedTouchesForTouch

Main Touches



Coalesced Touches

Touch Sequence

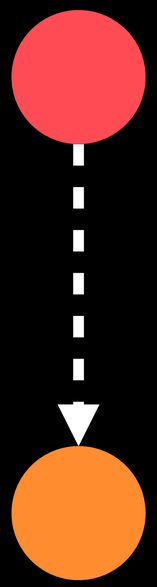


Main Touches

Coalesced Touches

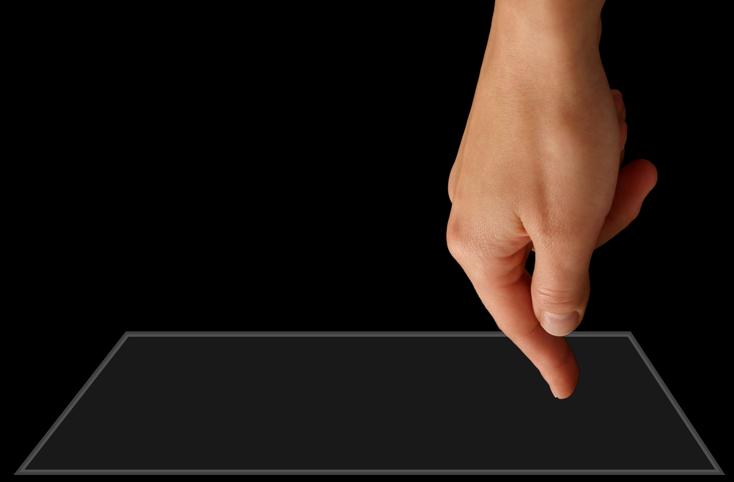
Touch Sequence

Main Touches

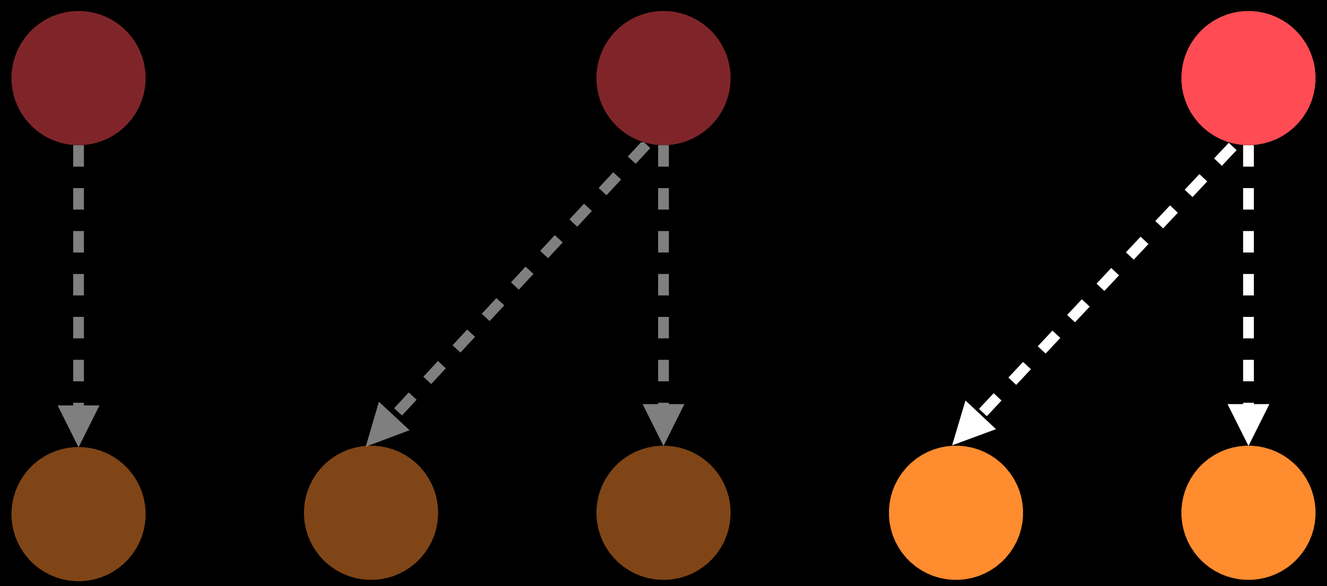


Coalesced Touches

Touch Sequence

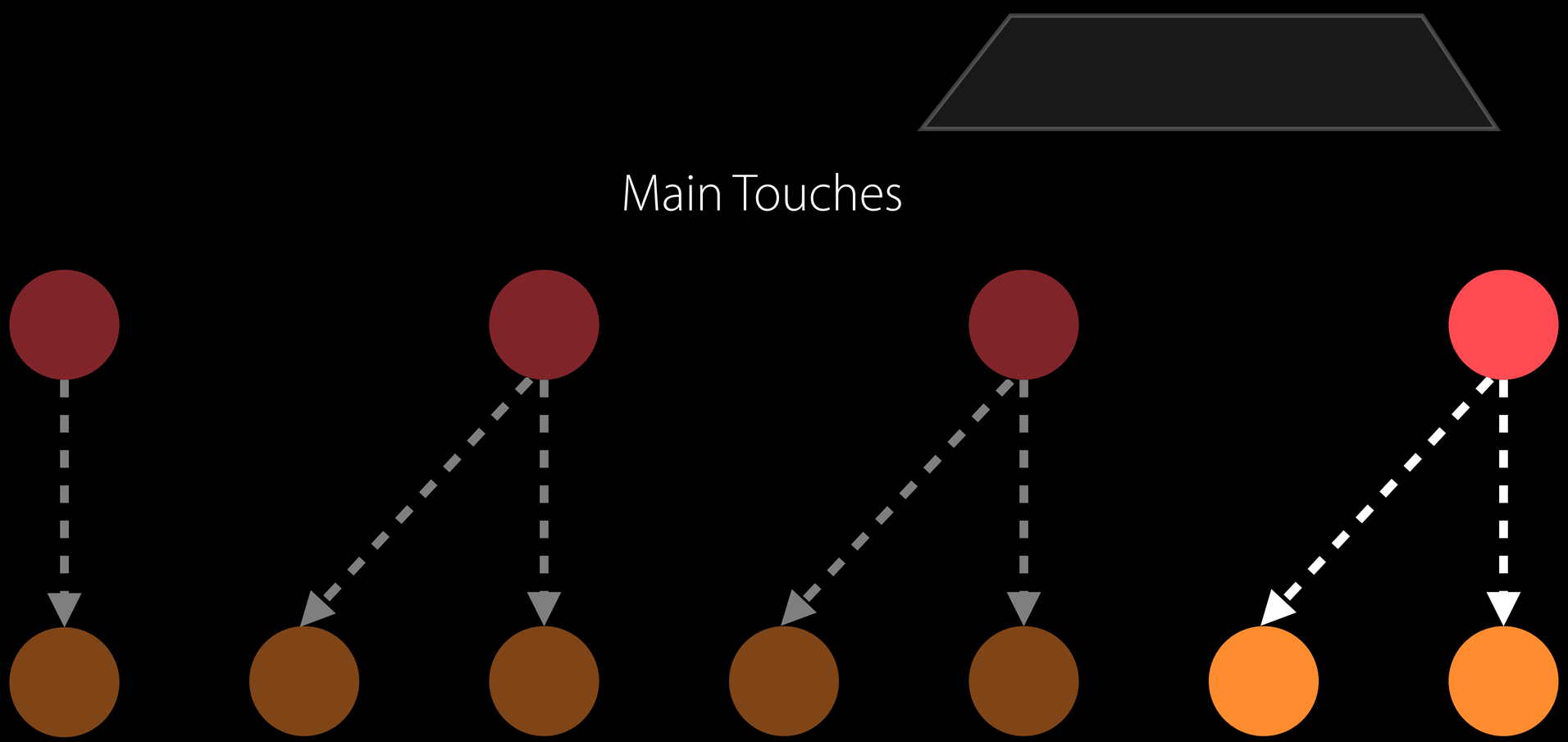


Main Touches



Coalesced Touches

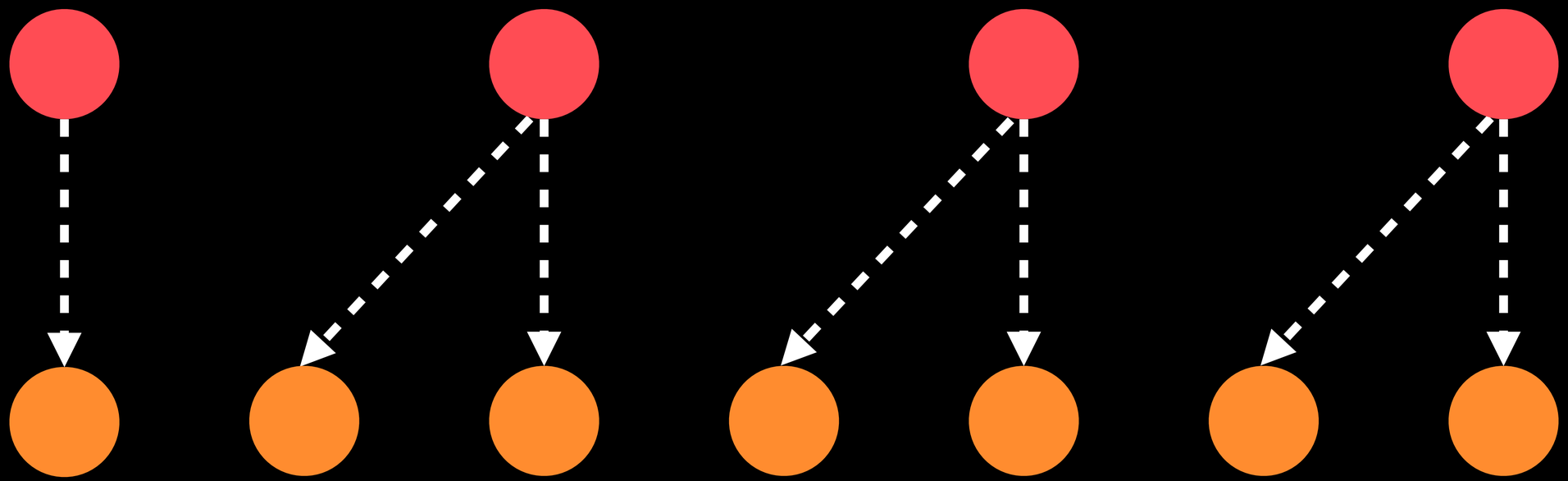
Touch Sequence



Previous Location

previousLocationInView

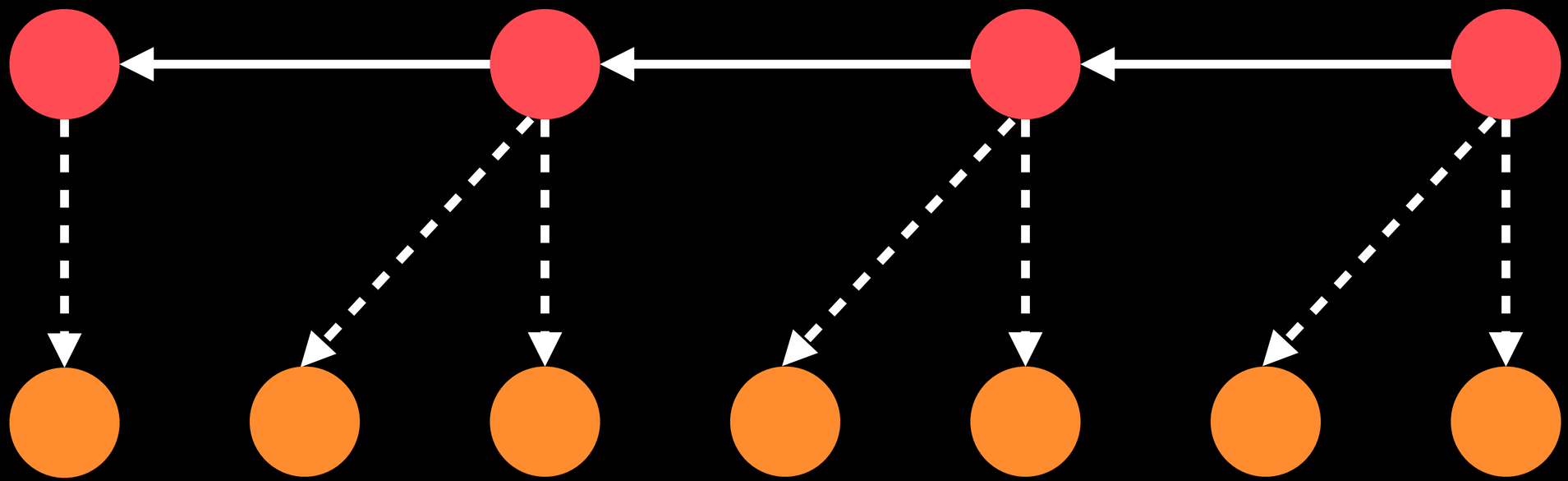
coalescedTouchesForTouch



Previous Location

previousLocationInView

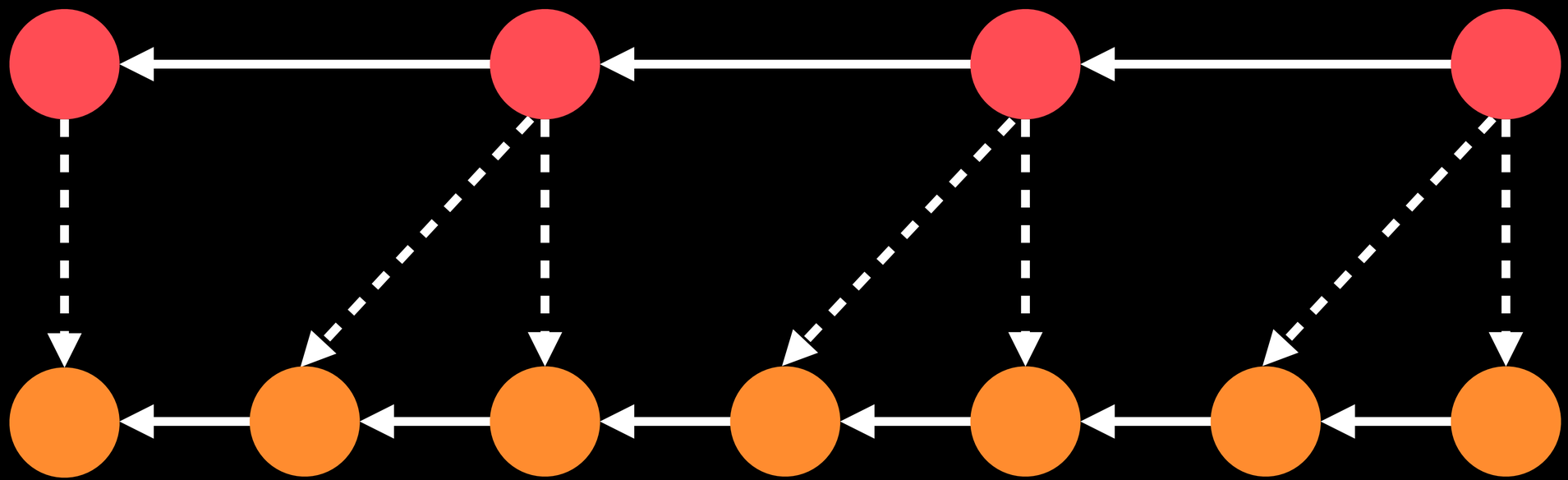
coalescedTouchesForTouch



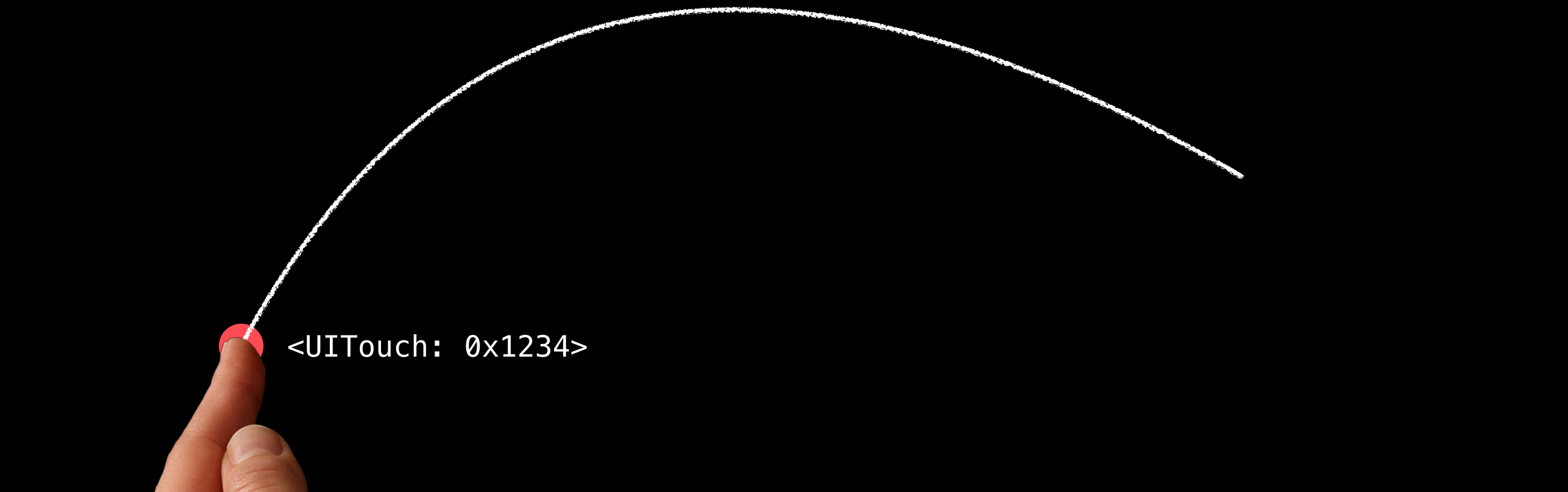
Previous Location

previousLocationInView

coalescedTouchesForTouch

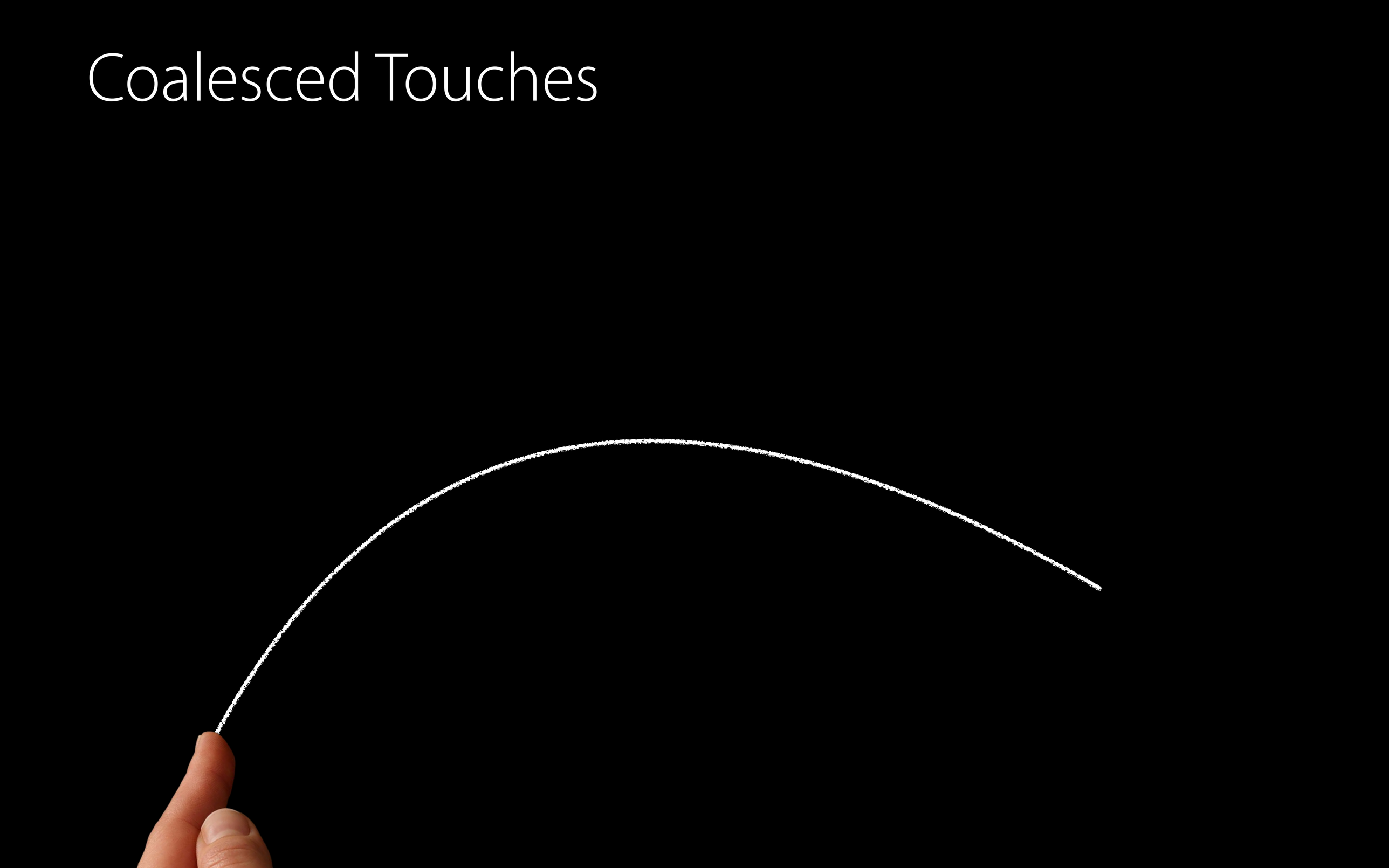


Main Touches

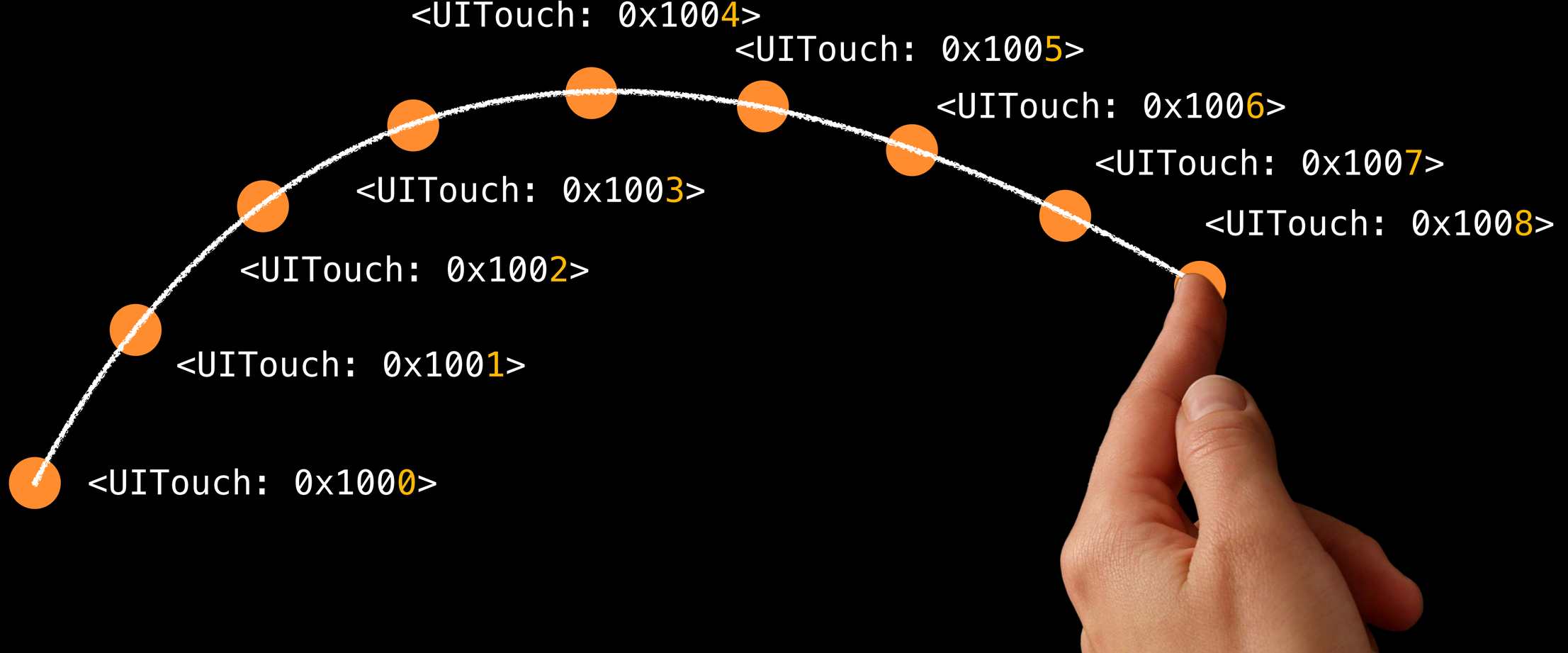


Main Touches

Coalesced Touches



Coalesced Touches



Touch Coalescing

```
for touch in touches {
    let line = lineForTouch(touch)
    addTouchSample(touch, toLine: line)
}
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    for coalescedTouch in event.coalescedTouchesForTouch(touch) {
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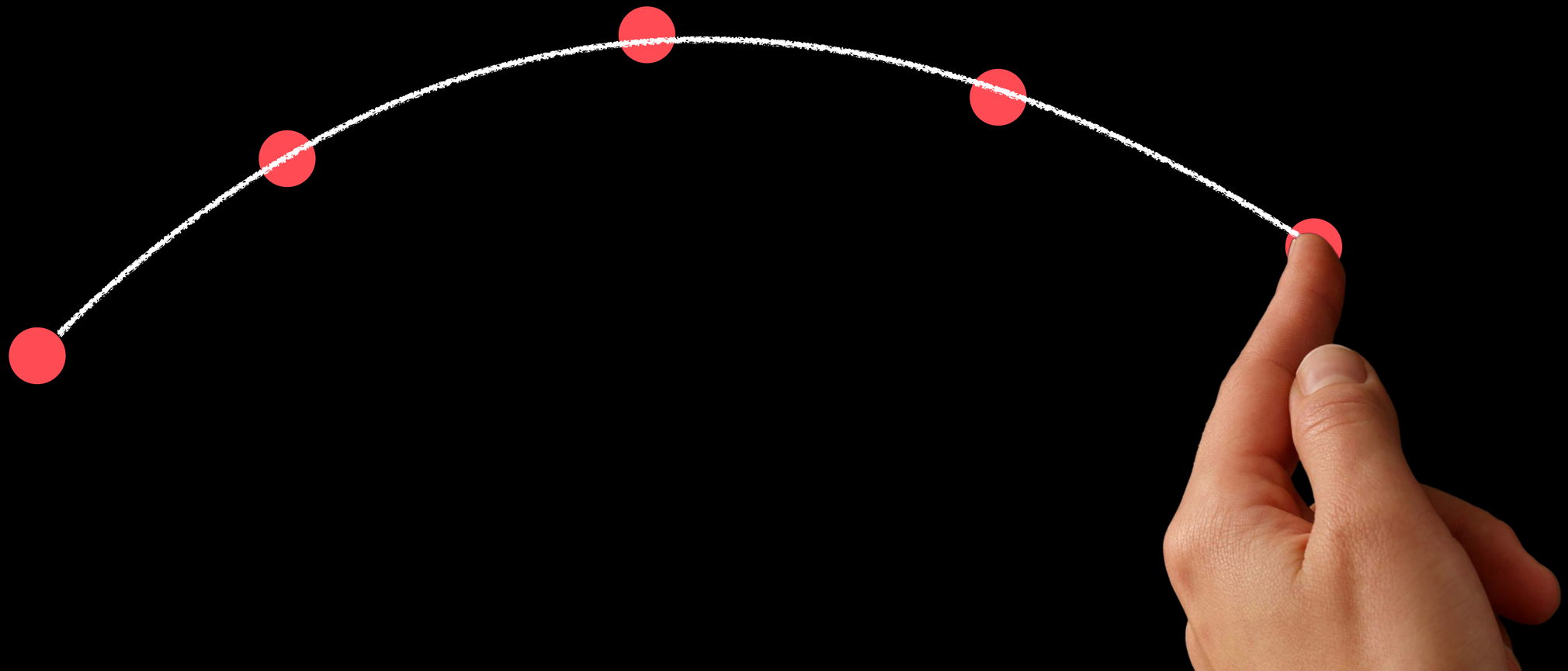
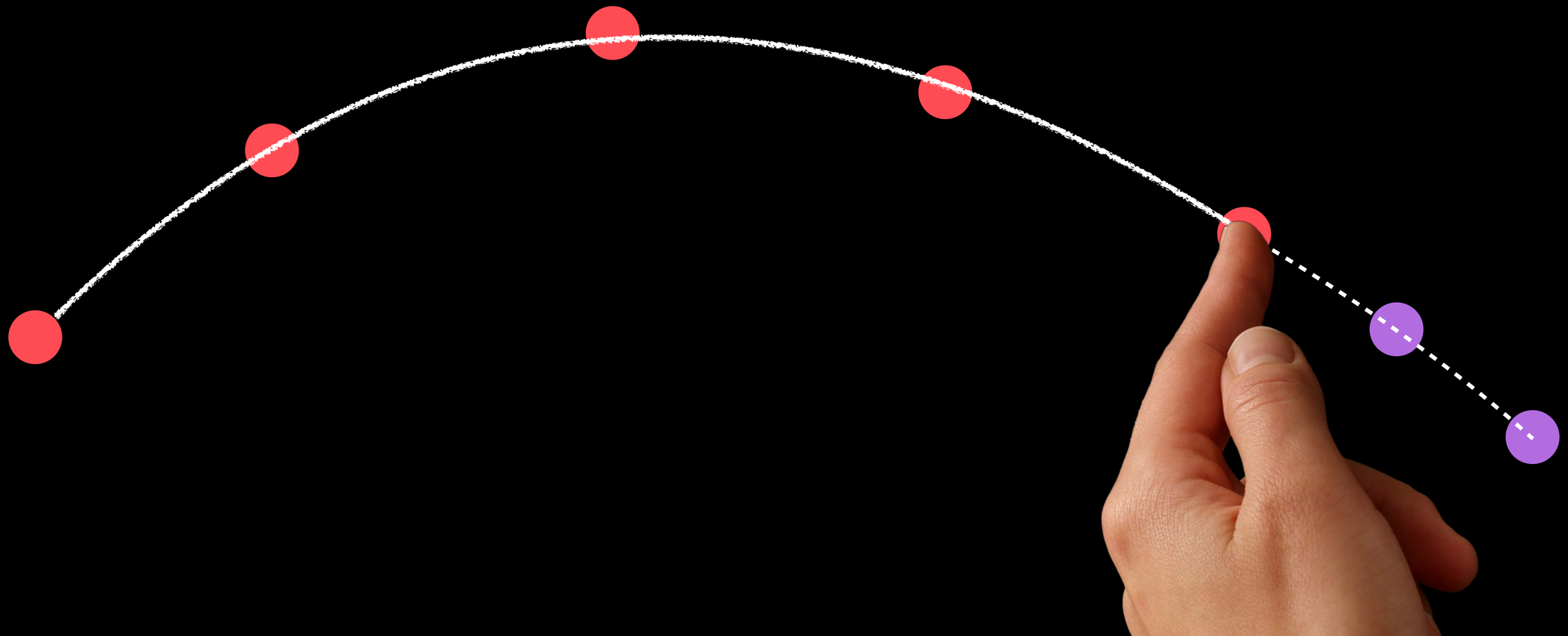
Touch Prediction

Touch Prediction



Touch Prediction

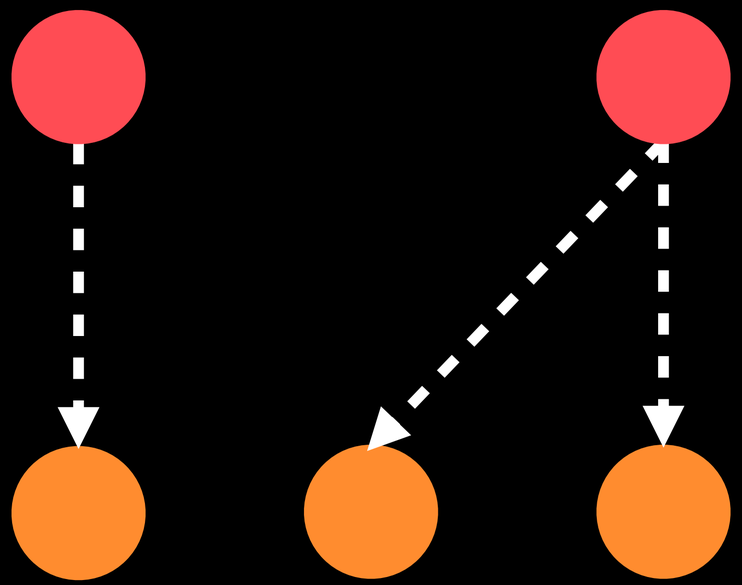


Touch Prediction

```
UIEvent.predictedTouchesForTouch(touch: UITouch)
    -> [UITouch]?
```

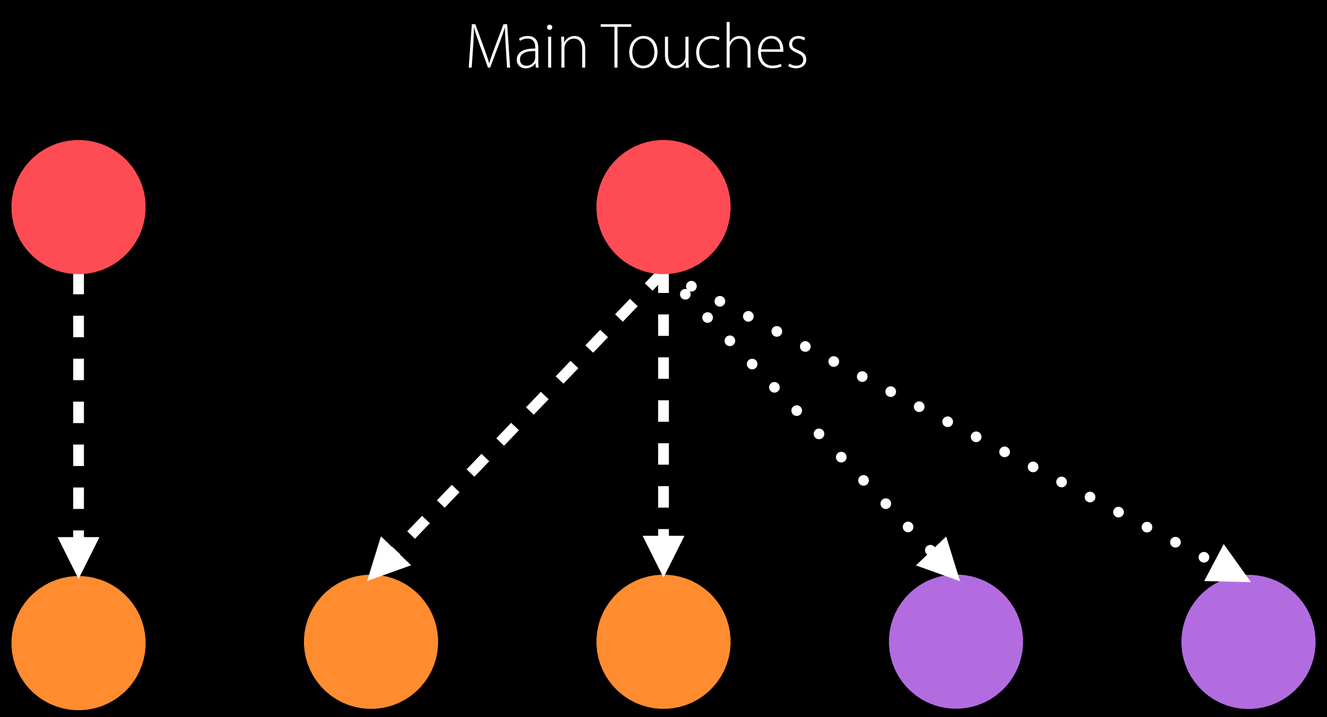
Touch Prediction

```
----▶  coalescedTouchesForTouch
·····▶  predictedTouchesForTouch
```



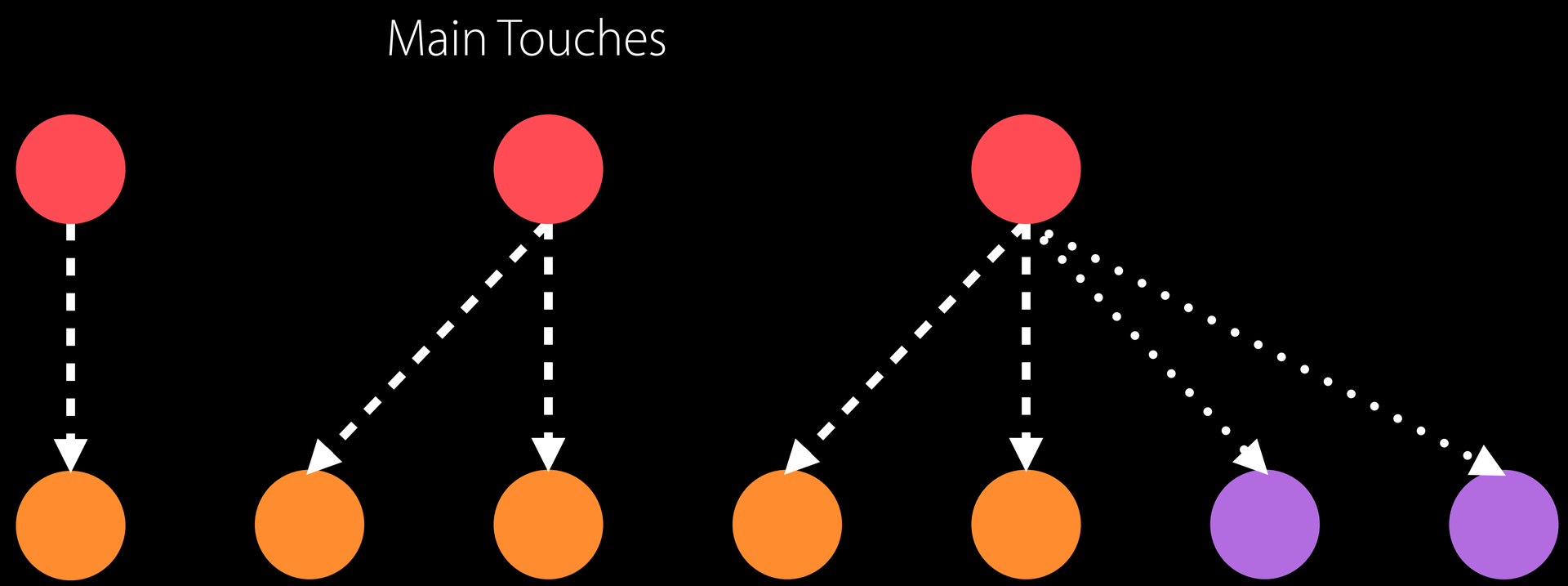
Touch Prediction

```
----▶  coalescedTouchesForTouch
·····▶  predictedTouchesForTouch
```



Touch Prediction

```
----▶  coalescedTouchesForTouch
·····▶  predictedTouchesForTouch
```

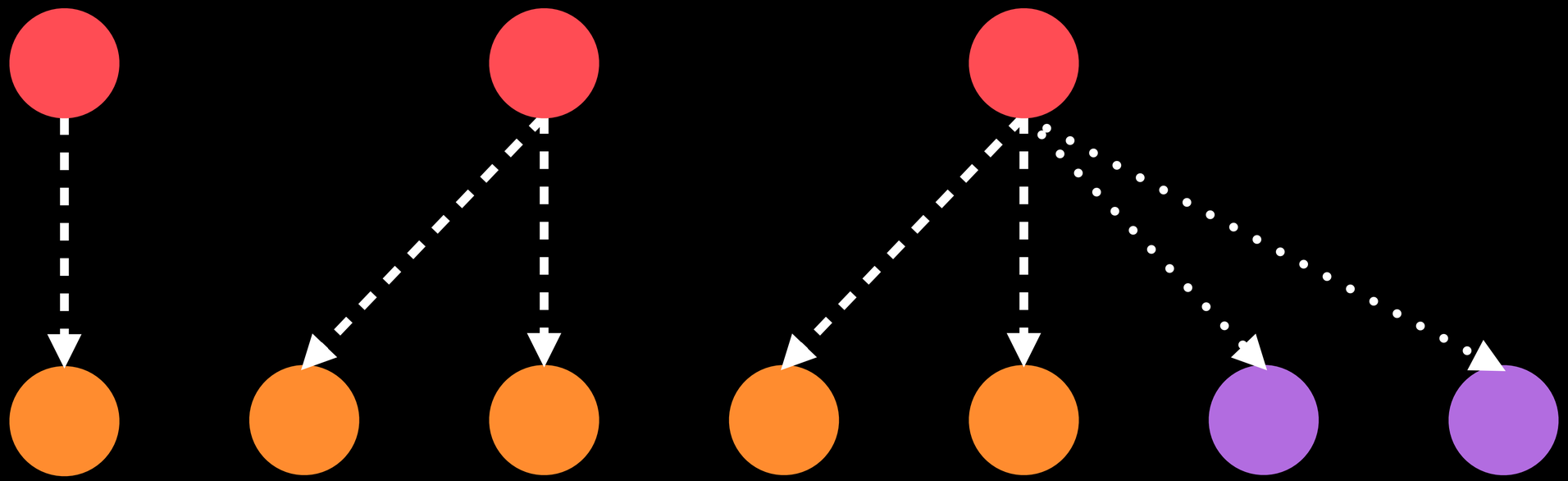


Touch Prediction

previousLocationInView

coalescedTouchesForTouch

predictedTouchesForTouch

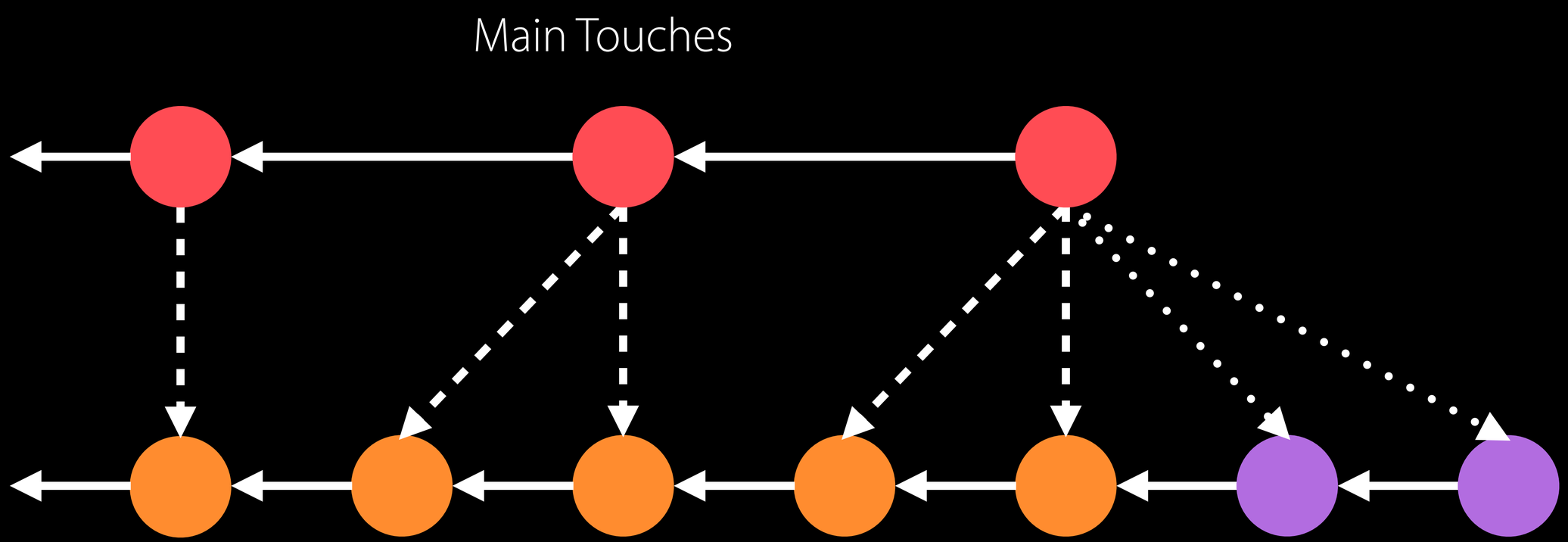


Touch Prediction

previousLocationInView

coalescedTouchesForTouch

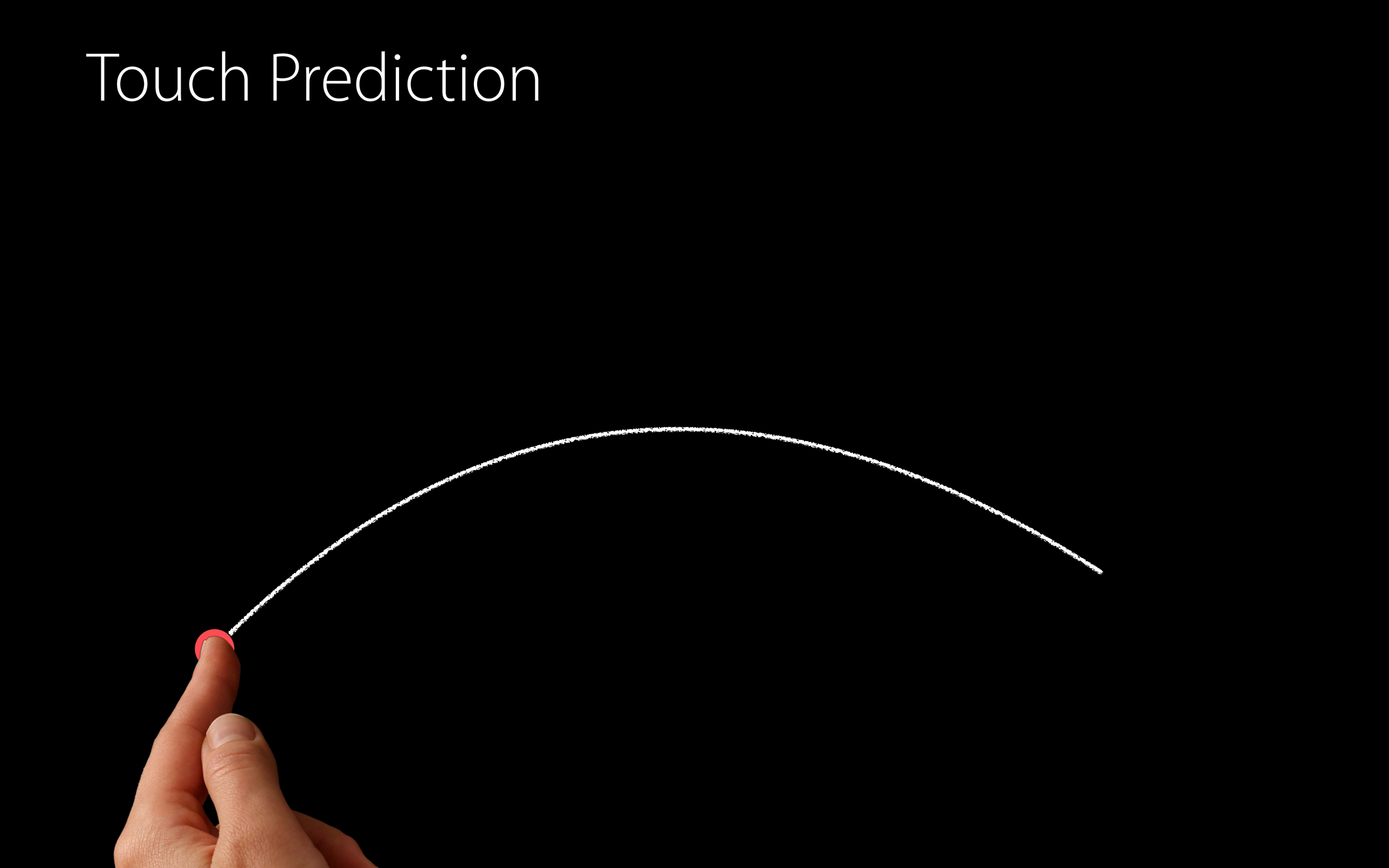
predictedTouchesForTouch



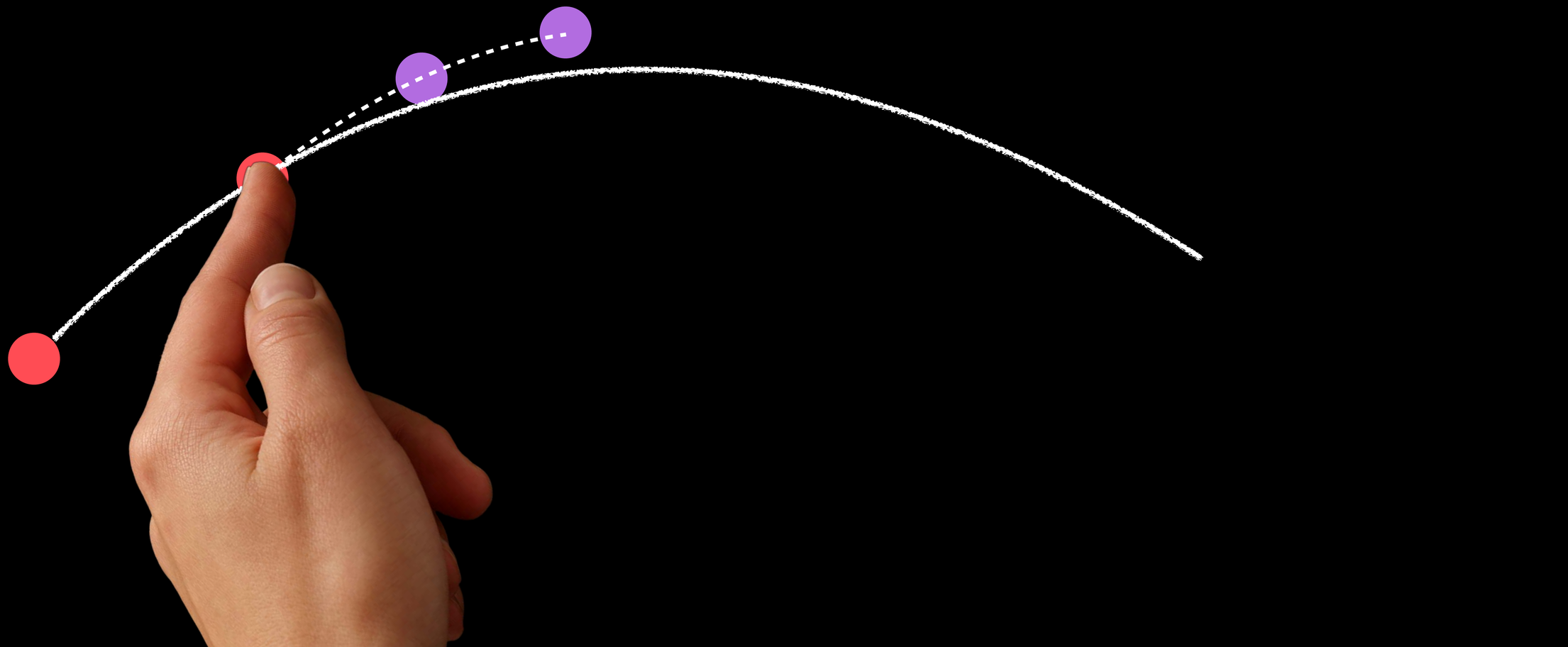
Touch Prediction

Touch Prediction

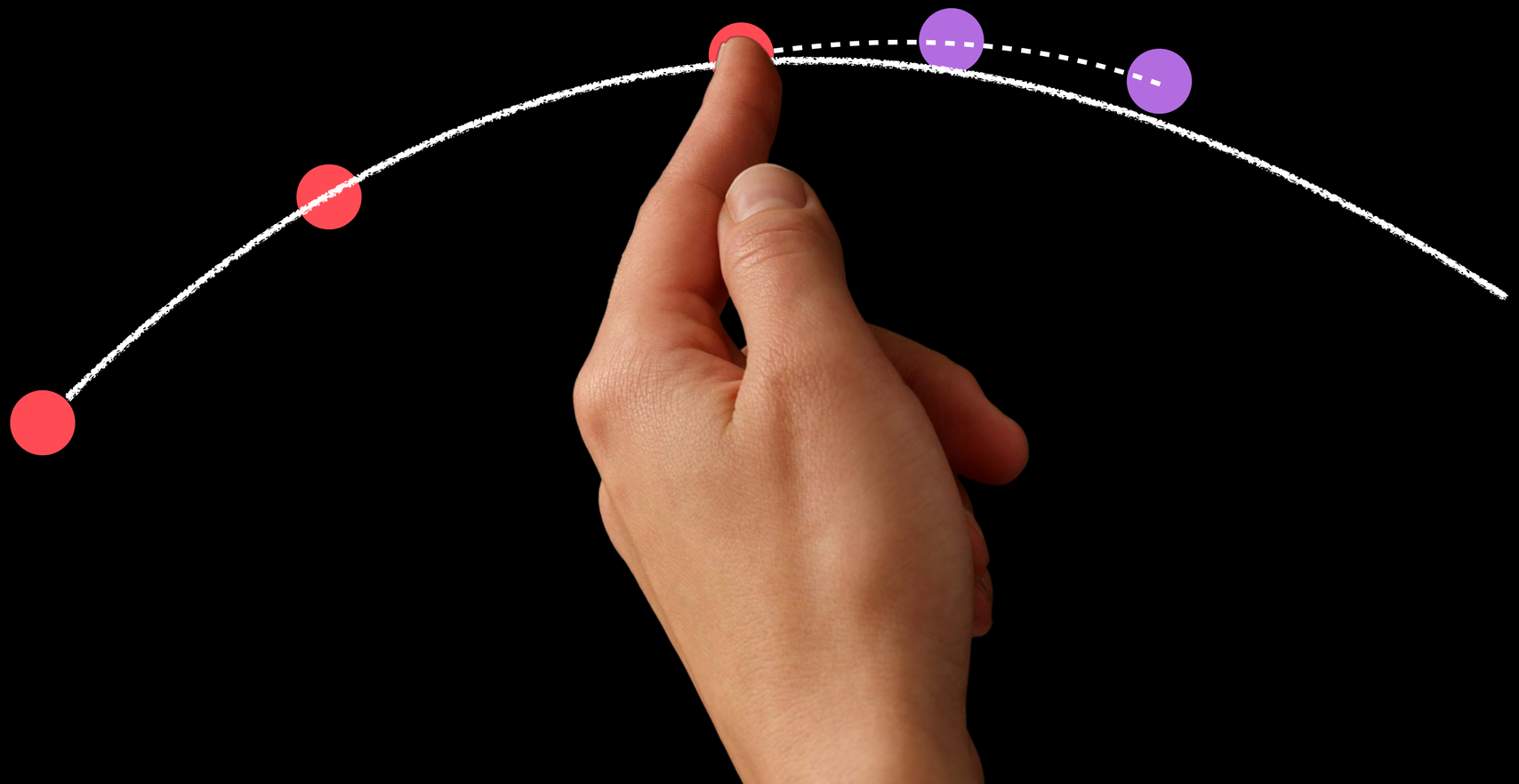
Touch Prediction



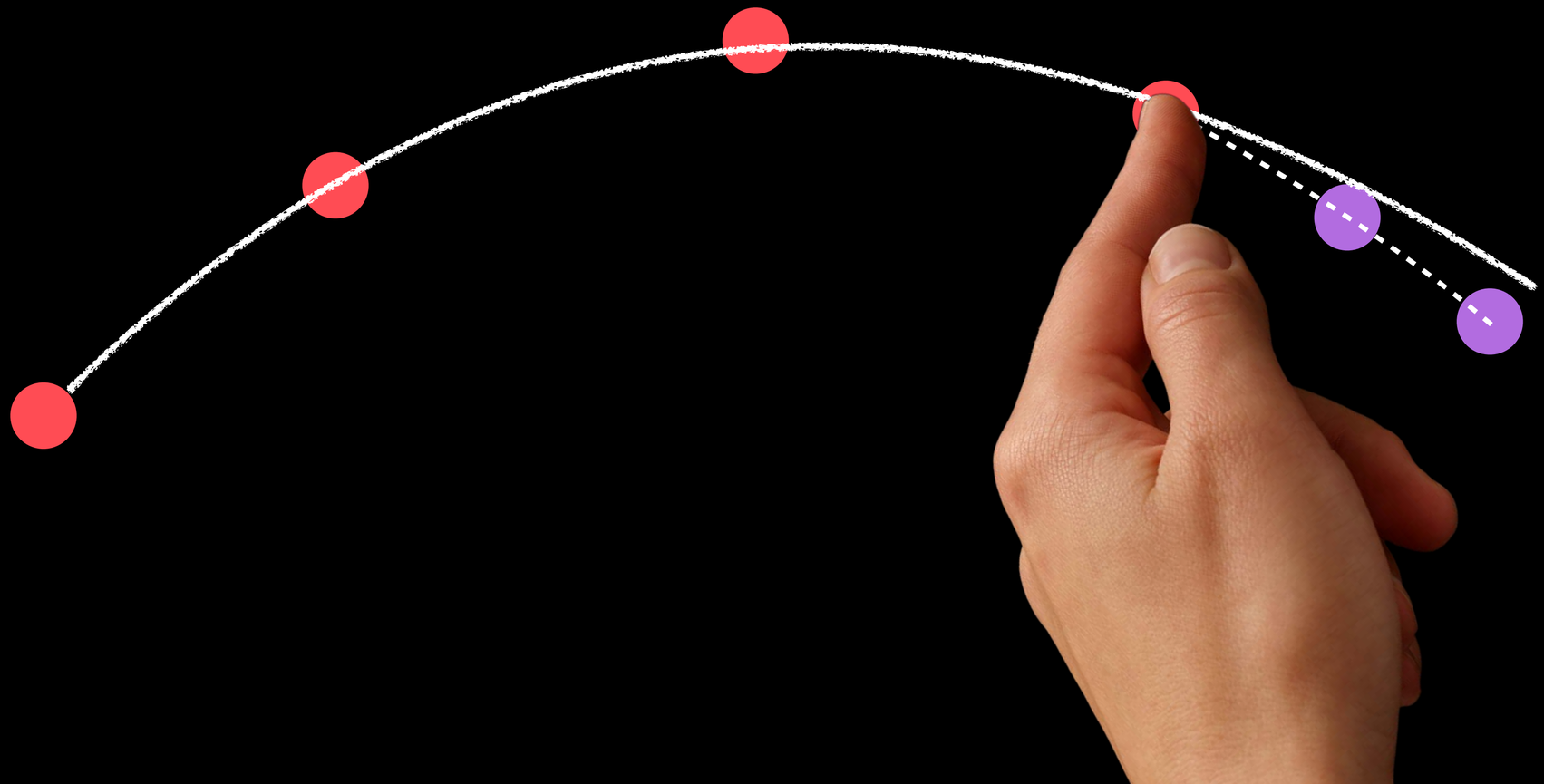
Touch Prediction



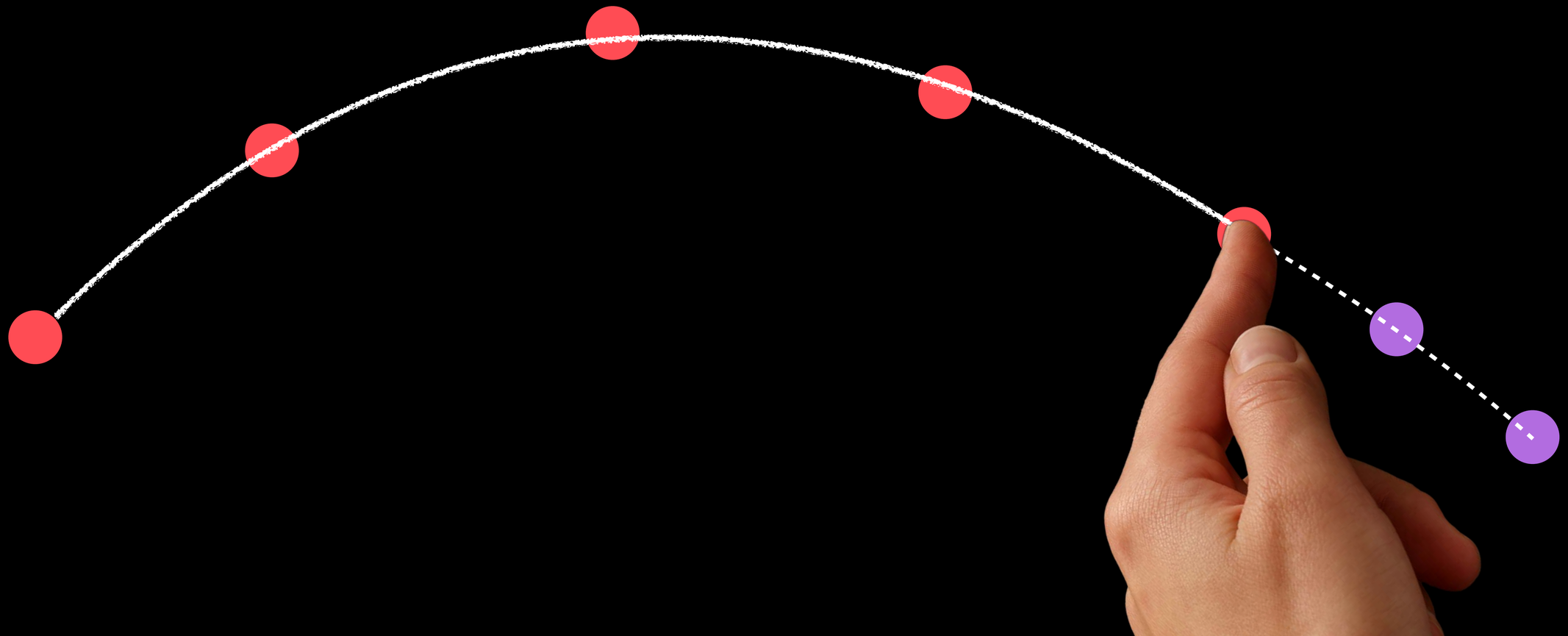
Touch Prediction



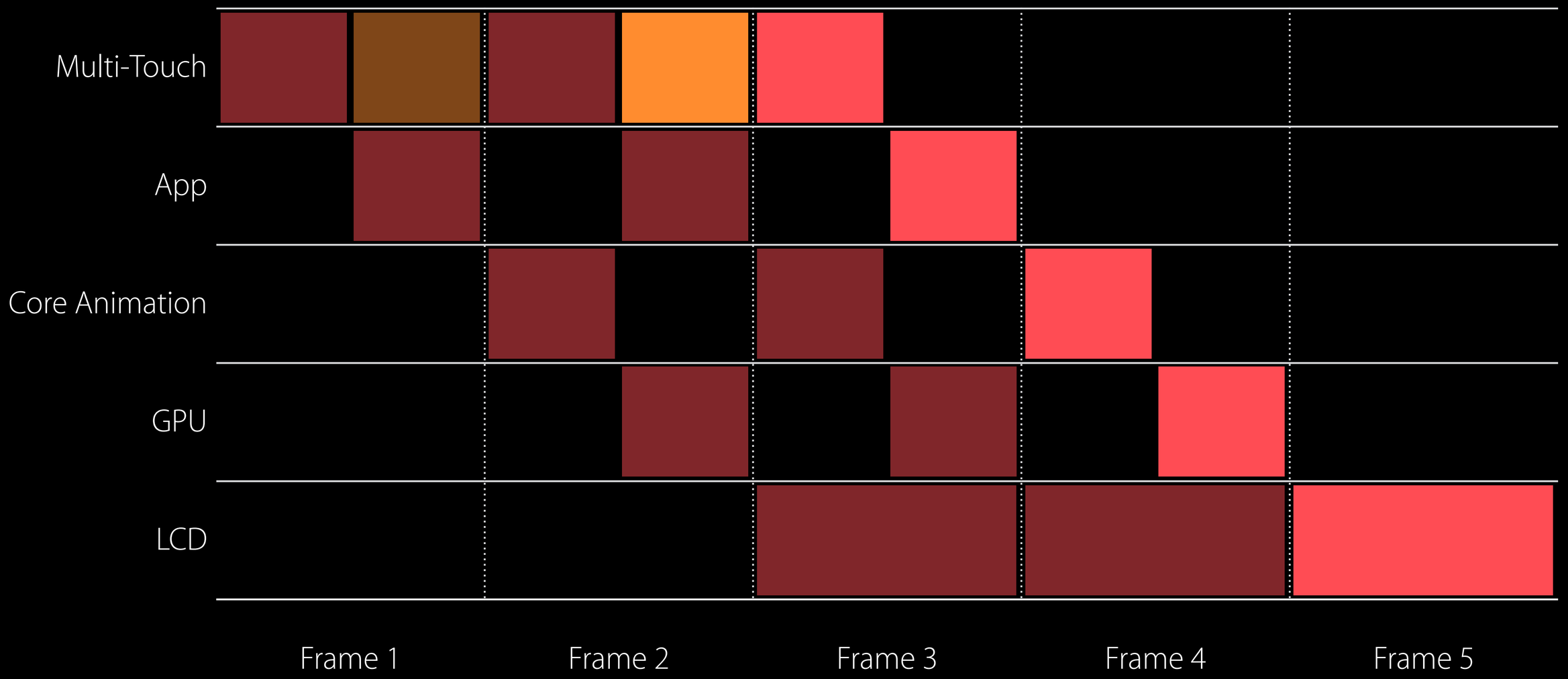
Touch Prediction



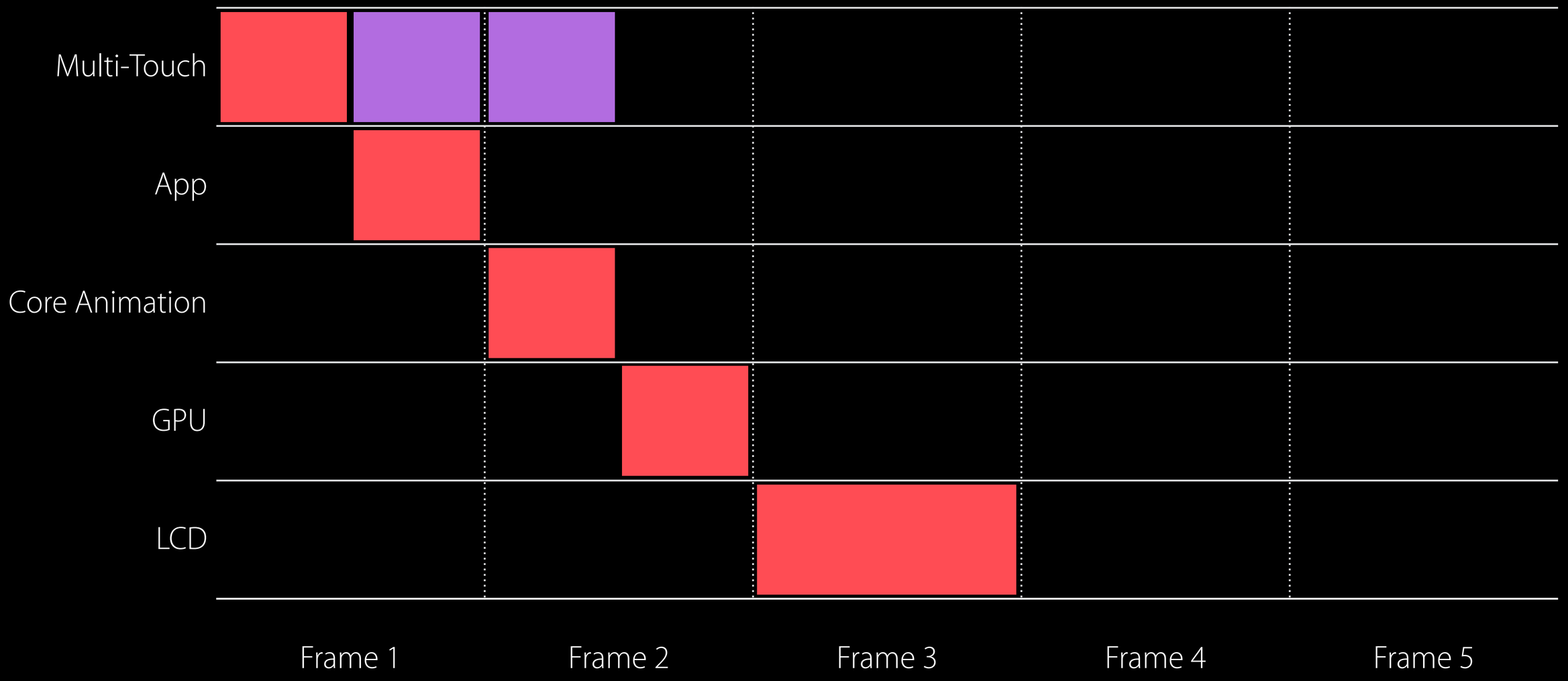
Touch Prediction



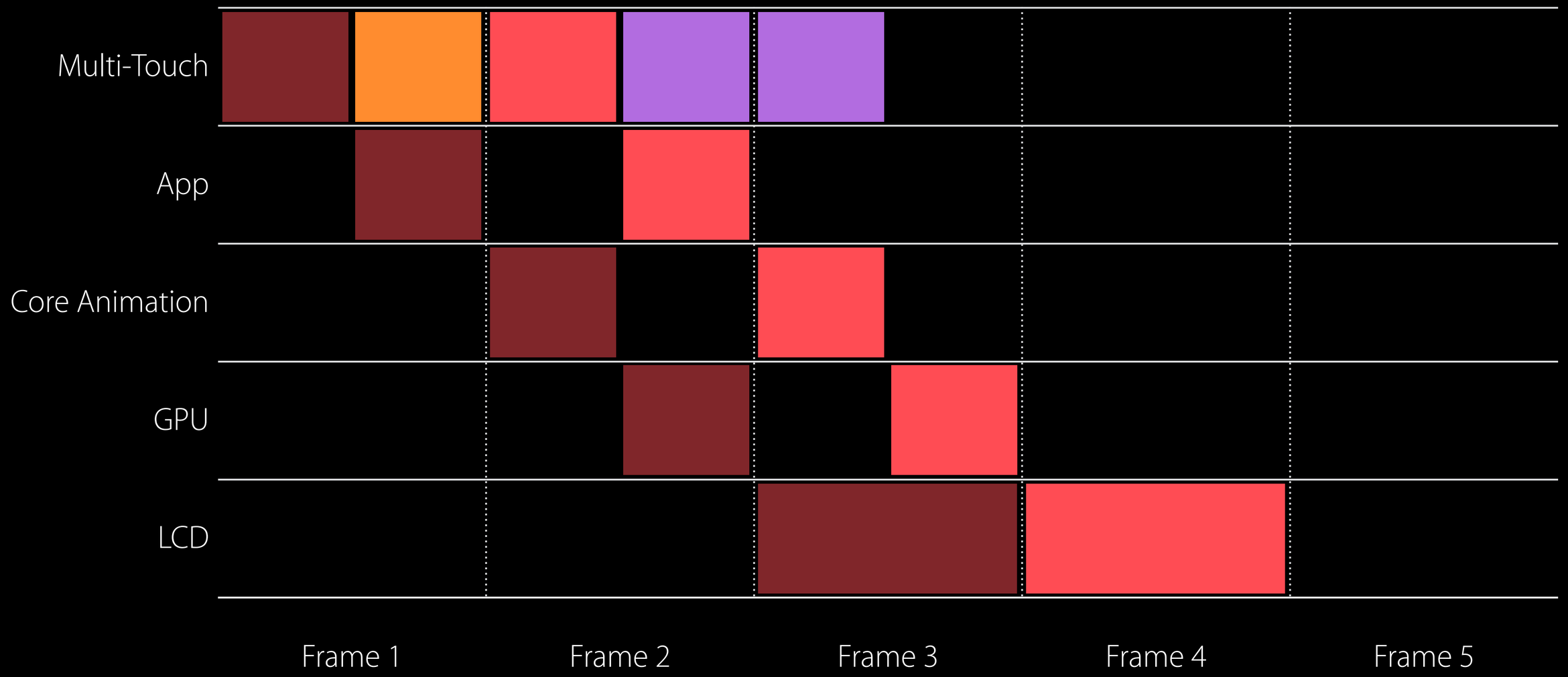
Coalesced Touches



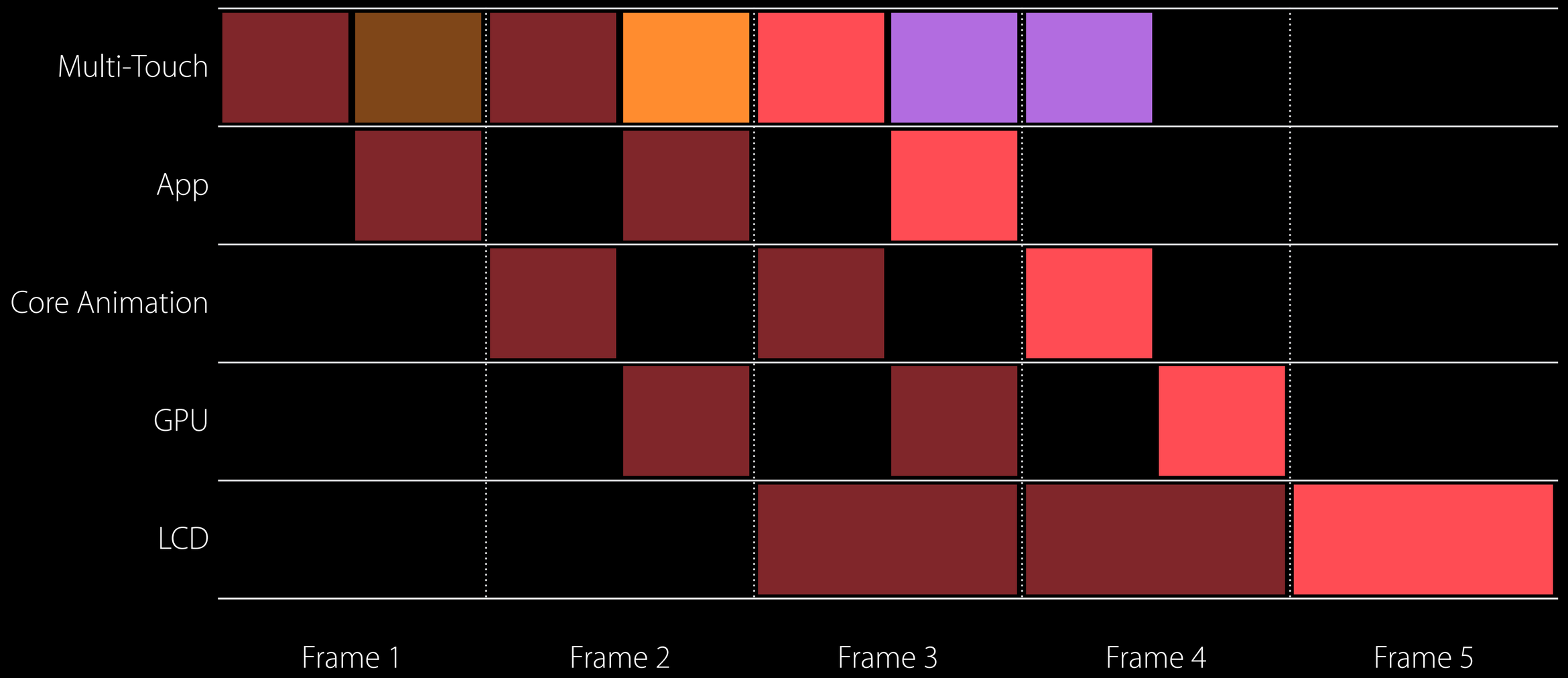
Coalesced and Predicted Touches



Coalesced and Predicted Touches



Coalesced and Predicted Touches



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Touch Prediction

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    for coalescedTouch in event.coalescedTouchesForTouch(touch) {
        addTouchSample(coalescedTouch, toLine: line)
    }
    removePredictedSamplesFromLine(line)
    for predictedTouch in event.predictedTouchesForTouch(touch) {
        addPredictedTouchSample(predictedTouch, toLine: line)
    }
}
```

Touch Prediction

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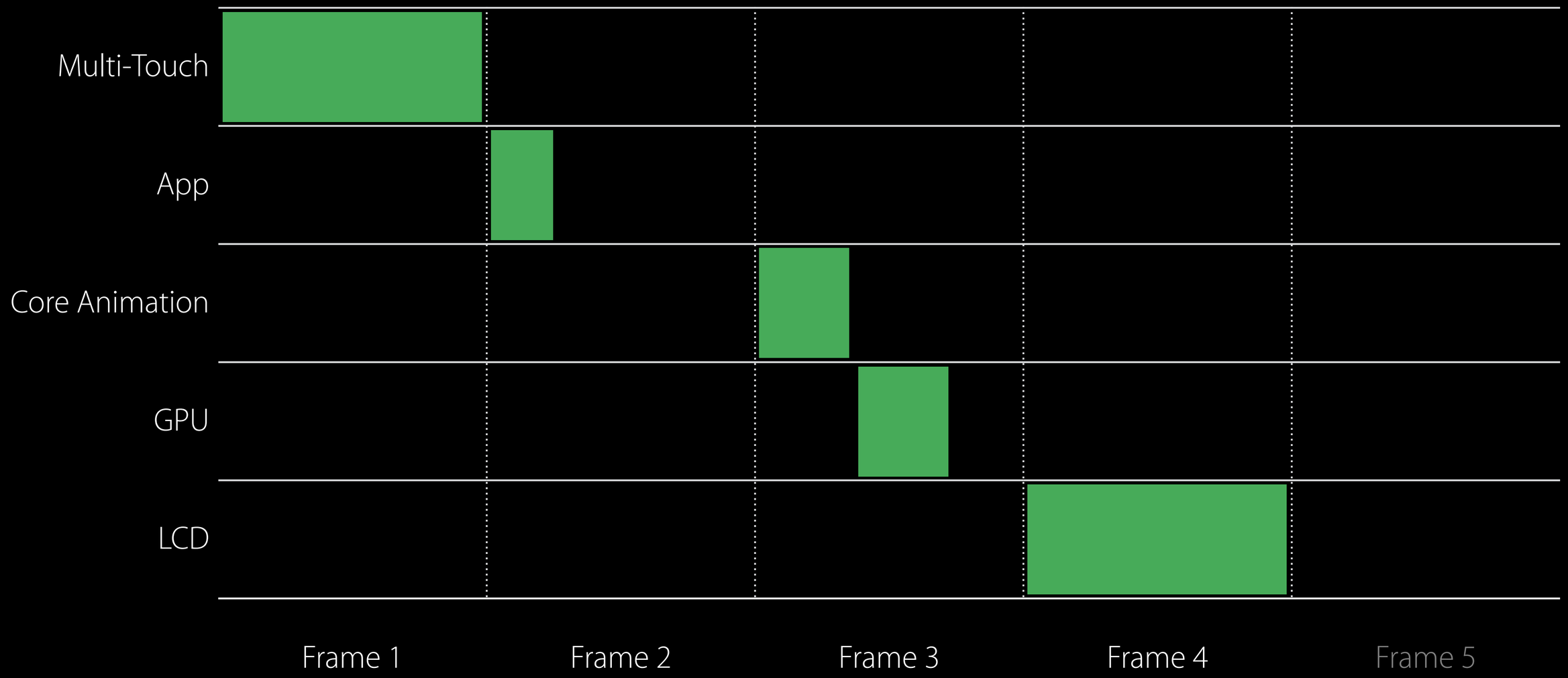
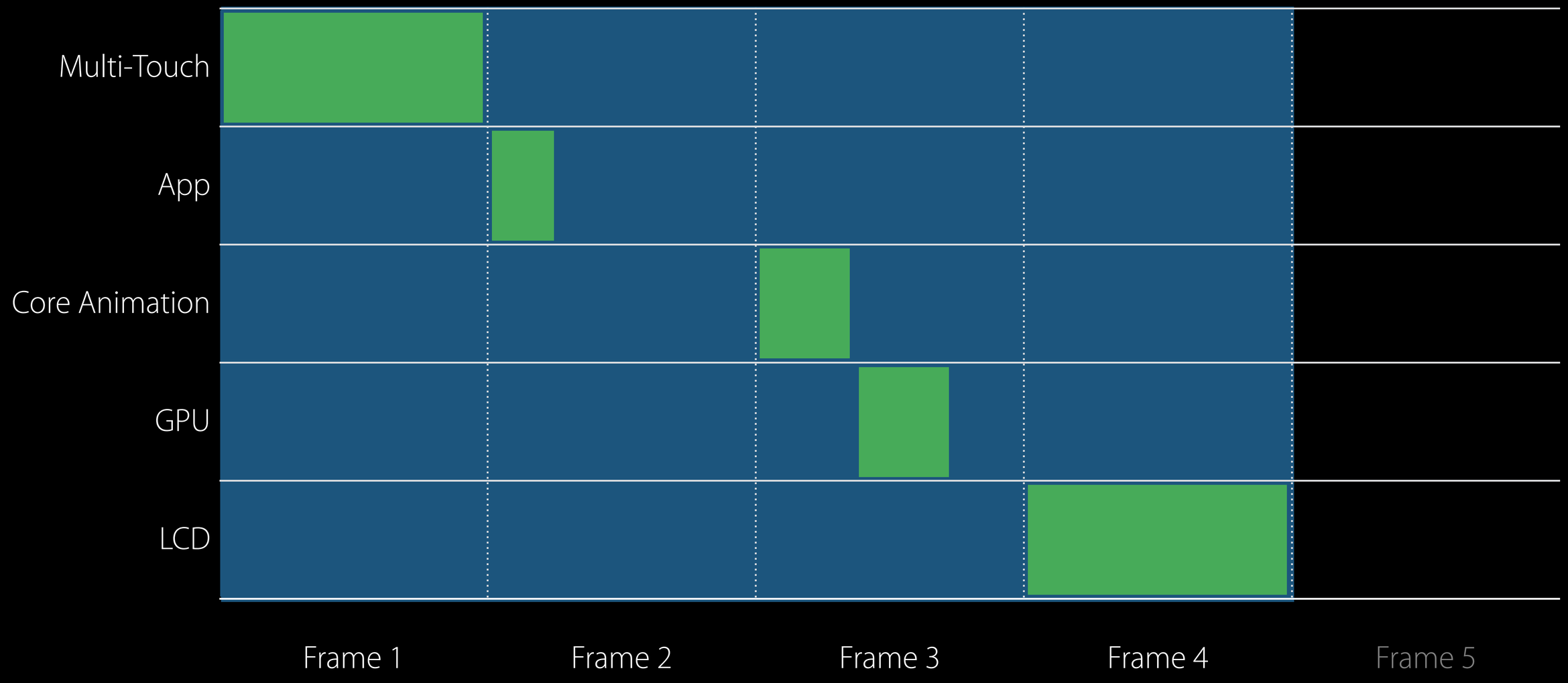
Putting It Together

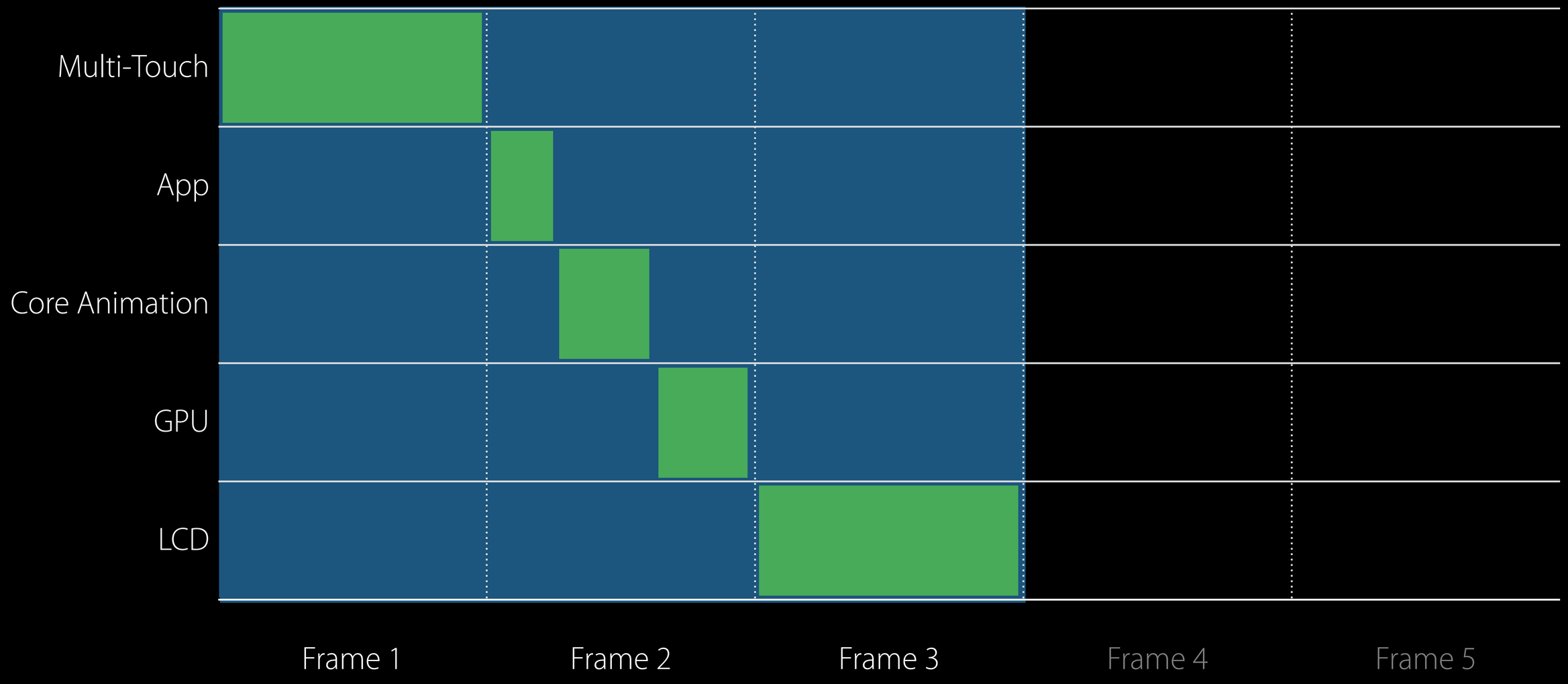
iOS 8


Multi-Touch
App
Core Animation
GPU
LCD
Frame 1
Frame 2
Frame 3
Frame 4
Frame 5

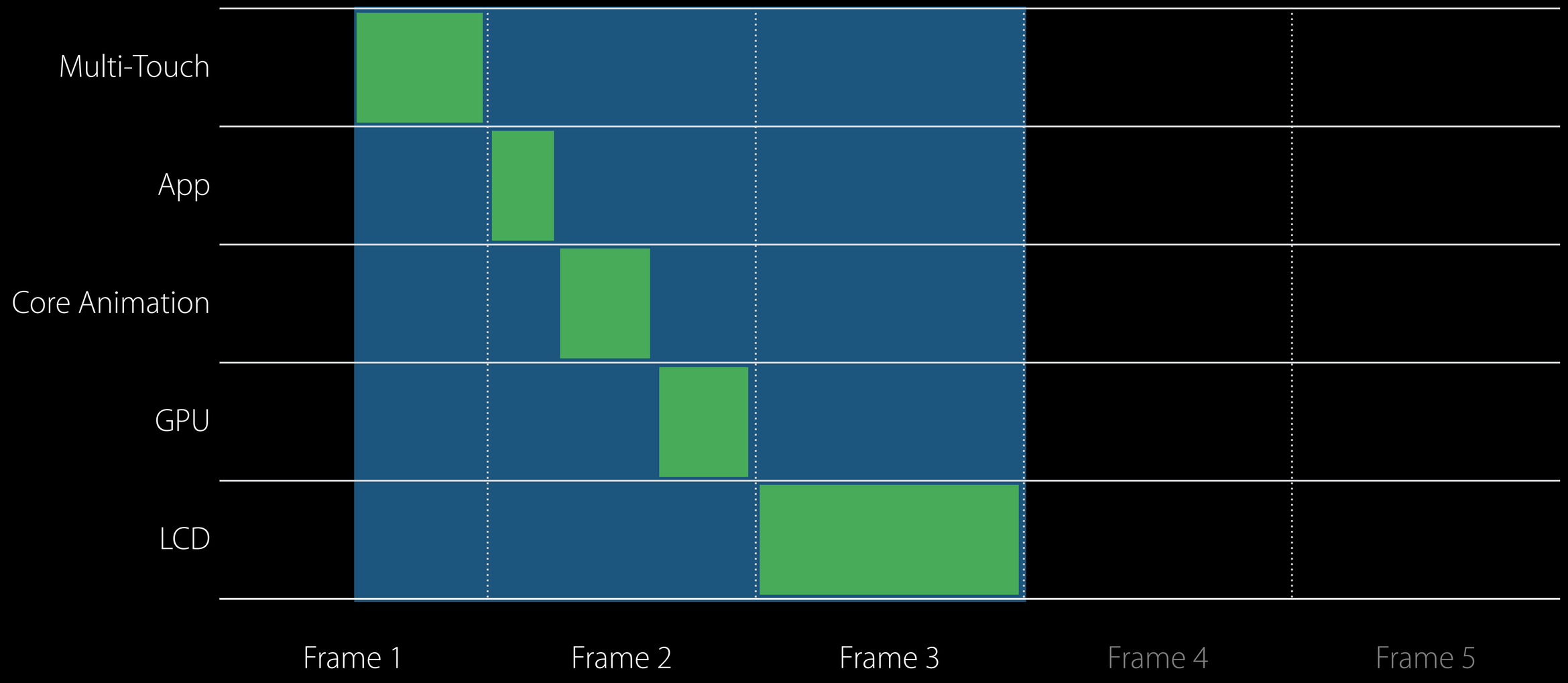
iOS 8


Multi-Touch
App
Core Animation
GPU
LCD
Frame 1
Frame 2
Frame 3
Frame 4
Frame 5

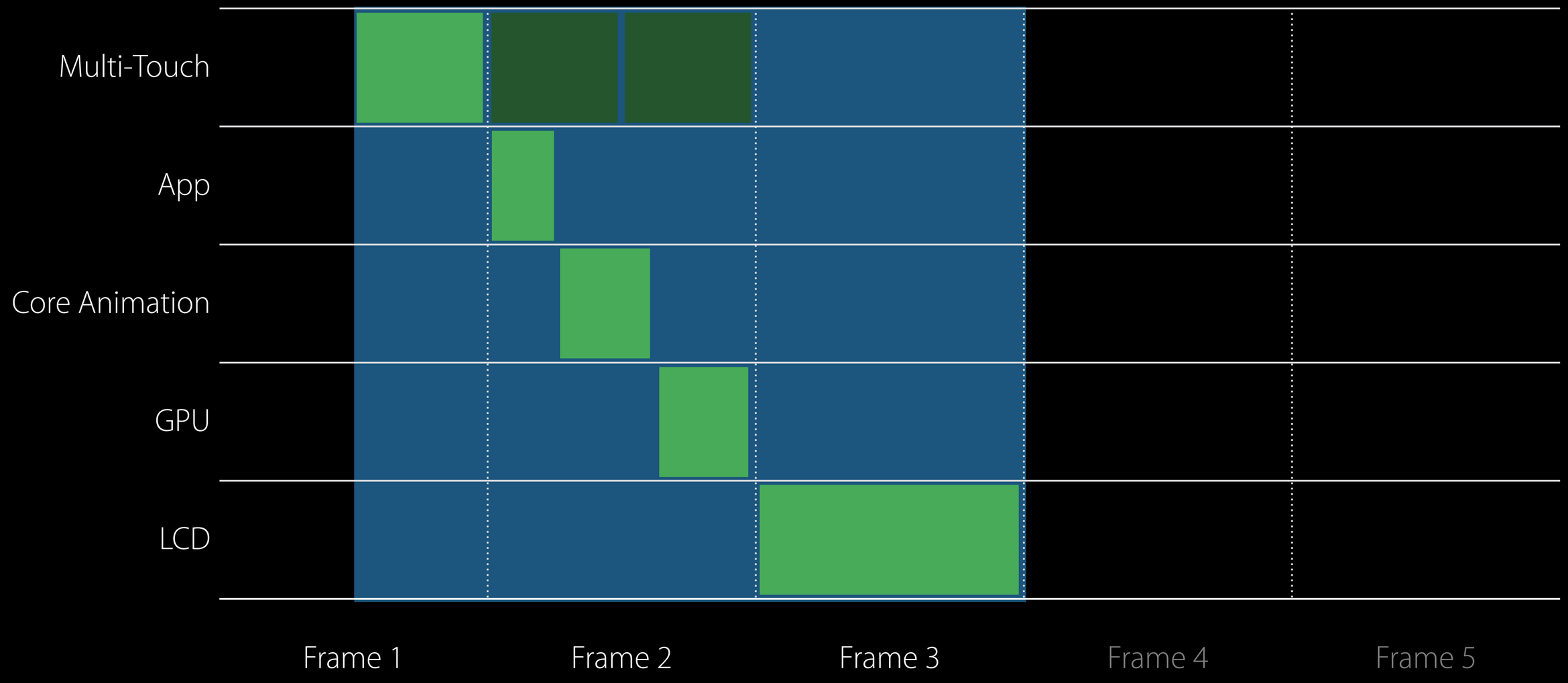
Low Latency Core Animation



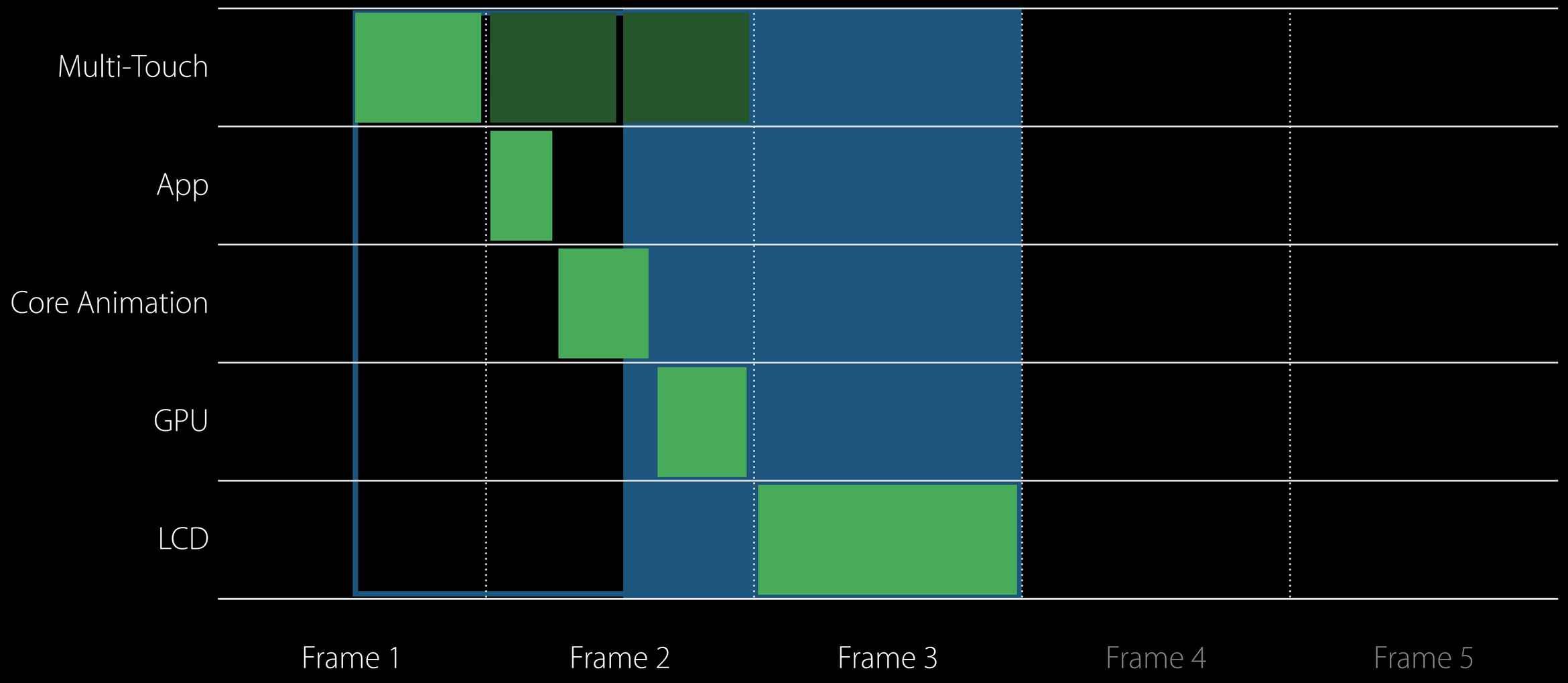
Touch Coalescing



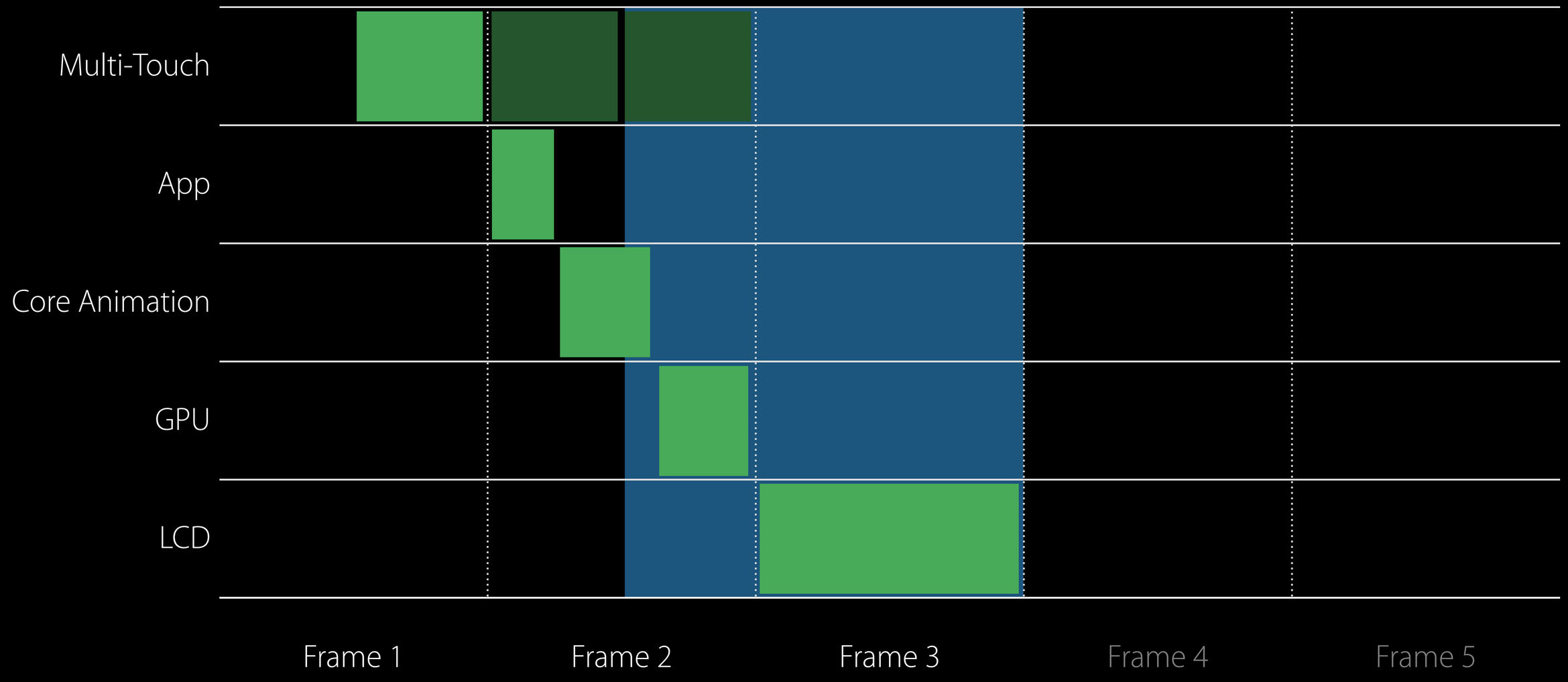
Touch Prediction



Touch Prediction



iOS 9


Multi-Touch
App
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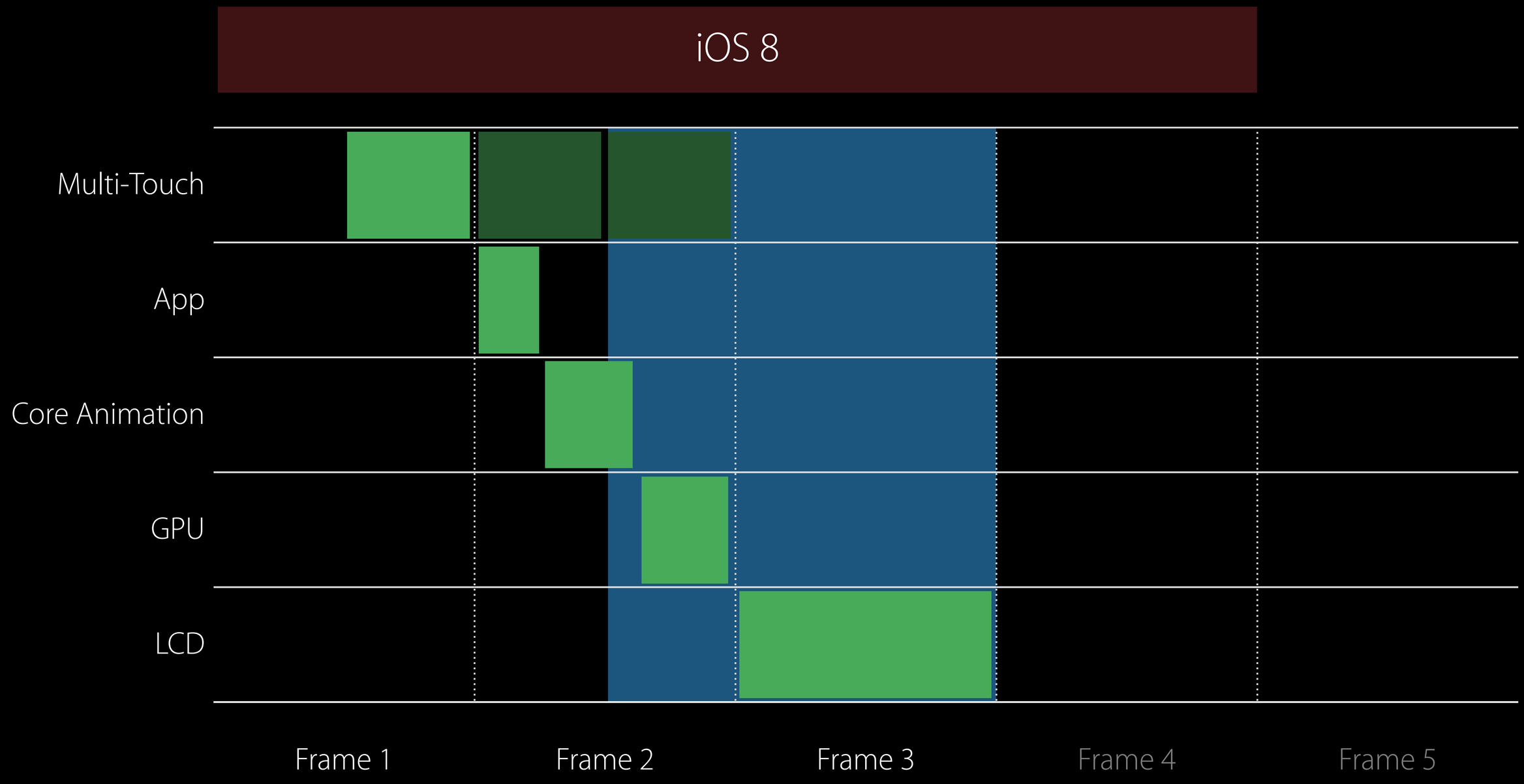
GPU
LCD
Frame 1
Frame 2
Frame 3
Frame 4
Frame 5

iOS 9


iOS 8
Multi-Touch
App
Core Animation
GPU
LCD
Frame 1
Frame 2
Frame 3
Frame 4
Frame 5

Fine-Tuning Your Application

Fine-Tuning Your Application

Only render what's visible

Ensure that the application only renders content that will actually make it on screen

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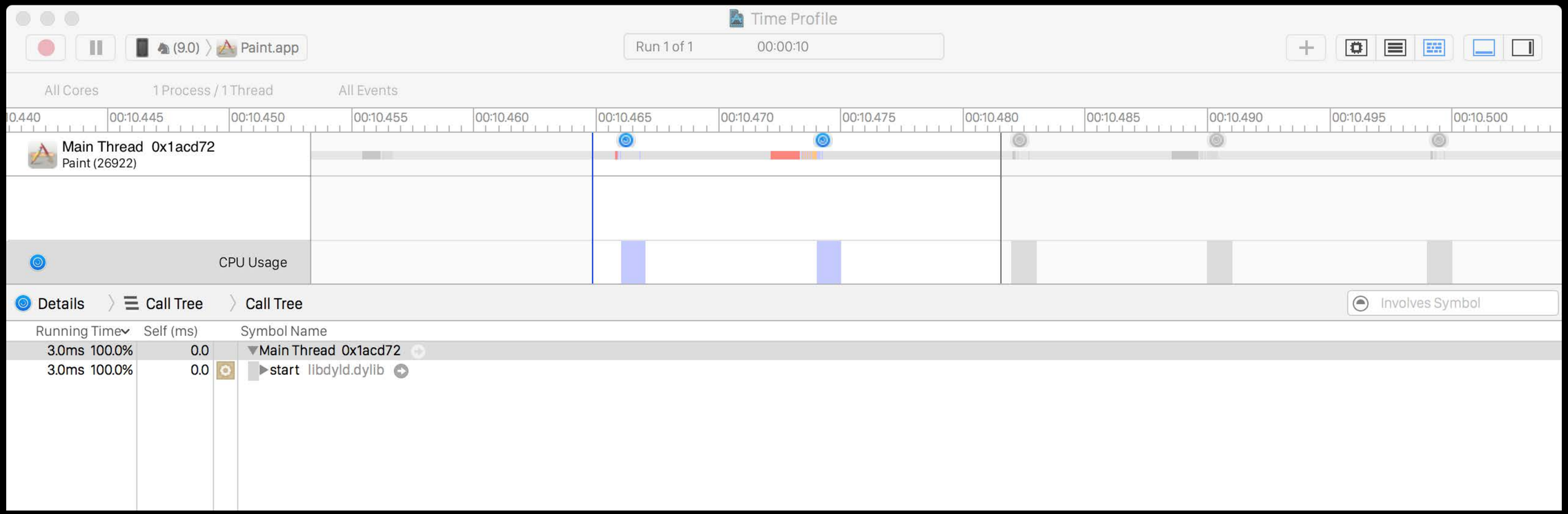
Profiling with Instruments

Time Profiler is a great way to find out how much your app is using the CPU



Fine-Tuning Your Application

Profiling GPU performance

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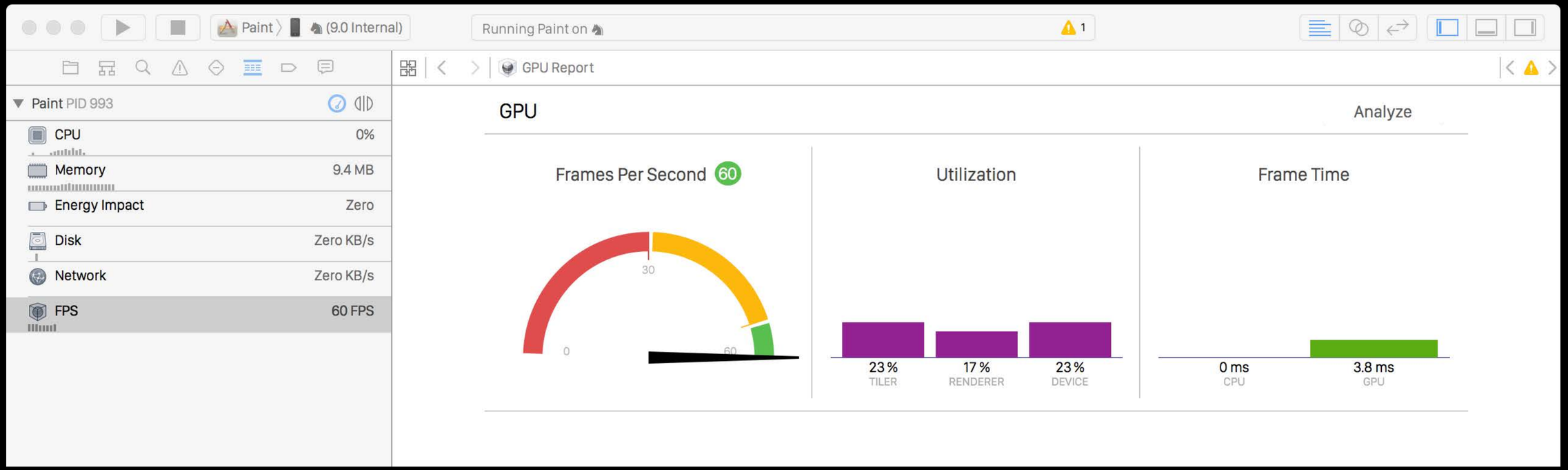
FPS Gauge and GPU Report give a high-level view of your GPU performance



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Profiling GPU performance

FPS Gauge and GPU Report give a high-level view of your GPU performance

The new GPU Driver Instrument can show you how long the GPU is active

Summary

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Reducing latency makes your application feel more alive

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Low Latency modes for Core Animation, OpenGL, and Metal

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Touch Prediction

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Instruments can help you understand your application's performance

More Information

Documentation

Performance Overview

Instruments User Guide

http://developer.apple.com/library

Technical Support

Apple Developer Forums

Developer Technical Support

General Inquiries

Curt Rothert, App Frameworks Evangelist

rothert@apple.com

Related Sessions

Metal Performance Optimization Techniques	Pacific Heights	Friday 11:00AM
Profiling in Depth	Mission	Thursday 3:30 PM
Advanced Graphics and Animation	WWDC14	

WWDC15