

Concurrency & Parallelism in UE4

Tips for programming with many CPU cores

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Synchronization Primitives

Atomics

Locking

Signaling

Waiting

FPlatformAtomics

- InterlockedAdd
- InterlockedCompareExchange [-Pointer]
- InterlockedDecrement [-Increment]
- InterlockedExchange [-Pointer]

64- and 128-bit overloads on supported platforms

Synchronization Primitives

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// Example

```
class FThreadSafeCounter
{
public:
    int32 Add( int32 Amount )
    {
        return FPlatformAtomics::InterlockedAdd(&Counter, Amount);
    }

private:
    volatile int32 Counter;
};
```

Synchronization Primitives

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Critical Sections

- FCriticalSection implements synchronization object
- FScopeLock for scope level locking using a critical section
- Fast if the lock is not activated

Spin Locks

- FSpinLock can be locked and unlocked
- Sleeps or spins in a loop until unlocked
- Default sleep time is 0.1 seconds

Synchronization Primitives

Atomics

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Semaphores

- Like mutex with signaling mechanism
- Only implemented for Windows and hardly used
- API will probably change
- Use FEvent instead

Synchronization Primitives

Atomics

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FEvent

- Blocks a thread until triggered or timed out
- Frequently used to wake up worker threads

FScopedEvent

- Wraps an FEvent that blocks on scope exit

```
// Example for scoped events
{
    FScopedEvent Event;
    DoWorkOnAnotherThread(Event.Get());

    // stalls here until other thread triggers Event
}
```

High Level Constructs

Containers

Helpers

General Thread-safety

- Most containers (TArray, TMap, etc.) are not thread-safe
- Use synchronization primitives in your own code where needed

TLockFreePointerList

- Lock free, stack based and ABA resistant
- Used by Task Graph system

TQueue

- Uses a linked list under the hood
- Lock and contention free for SPSC
- Lock free for MPSC

TDisruptor (currently not part of UE4)

- Lock free MPMC queue using a ring buffer

High Level Constructs

Containers

Helpers

FThreadSafeCounter

FThreadSingleton

- Singleton that creates an instance per thread

FMemStack

- Fast, temporary per-thread memory allocation

TLockFreeClassAllocator, TLockFreeFixedSizeAllocator

- Another fast allocator for instances of T

FThreadIdleStats

- Measures how often a thread is idle

Parallelization

Threads

Task Graph

Processes

Messaging

FRunnable

- Platform agnostic interface
- Implement Init(), Run(), Stop() and Exit() in your sub-class
- Launch with FRunnableThread::Create()
- FSingleThreadRunnable when multi-threading is disabled

FQueuedThreadPool

- Carried over from UE3 and still works the same way
- Global general purpose thread pool in GThreadPool
- Not lock free

Parallelization

Threads

Task Graph

Processes

Messaging

Game Thread

- All game code, Blueprints and UI
- UObjects are not thread-safe!

Render Thread

- Proxy objects for Materials, Primitives, etc.

Stats Thread

- Engine performance counters

Parallelization

Threads

Task Graph

Processes

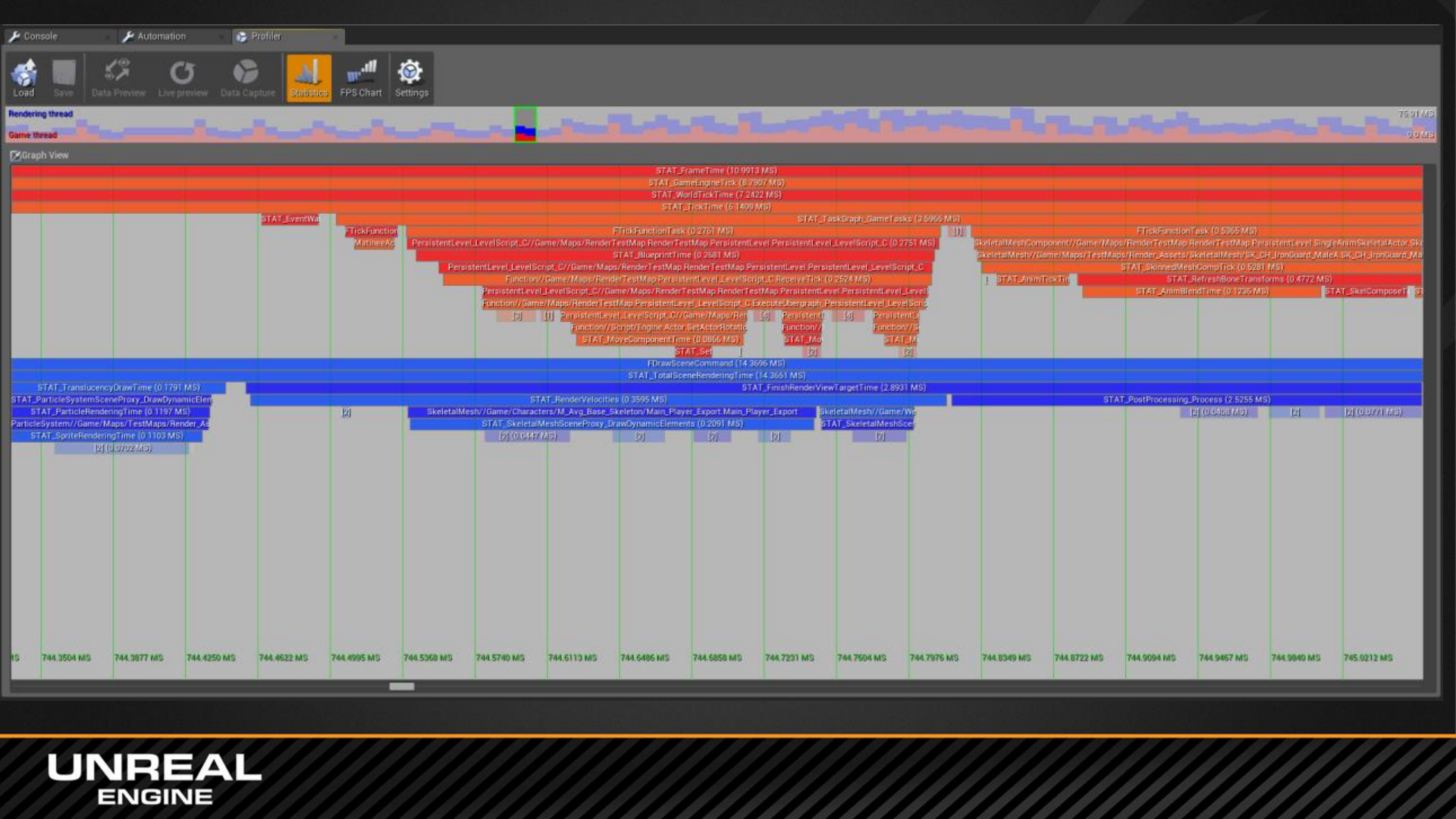
Messaging

Task Based Multi-Threading

- Small units of work are pushed to available worker threads
- Tasks can have dependencies to each other
- Task Graph will figure out order of execution

Used by an increasing number of systems

- Animation evaluation
- Message dispatch and serialization in Messaging system
- Object reachability analysis in garbage collector
- Render commands in Rendering sub-system
- Various tasks in Physics sub-system
- Defer execution to a particular thread



Parallelization

Threads

Task Graph

Processes

Messaging

FPlatformProcess

- CreateProc() executes an external program
- LaunchURL() launches the default program for a URL
- IsProcRunning() checks whether a process is still running
- Plus many other utilities for process management

FMonitoredProcess

- Convenience class for launching and monitoring processes
- Event delegates for cancellation, completion and output

Parallelization

Threads

Task Graph

Processes

Messaging

Unreal Message Bus (UMB)

- Zero configuration intra- and inter-process communication
- Request-Reply and Publish-Subscribe patterns supported
- Messages are simple UStructs

Transport Plug-ins

- Seamlessly connect processes across machines
- Only implemented for UDP right now (prototype)

Window

Endpoints

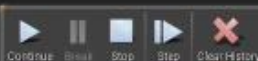
Endpoint Filter

Name

[-]	[-]	FMessageBridge (612E398A-47D8-2E91-E166-D0979)
[-]	[-]	FMessageBridge (DC52E5D0-4672-2F2D-1777-6199F)
[-]	[-]	FSessionService
[-]	[-]	FEngineService
[-]	[-]	FMessageBridge (53DC4693-491C-0670-B1DC-966F)
[-]	[-]	FMessageBridge (A712320B-4F18-6796-9400-FF9D)
[-]	[-]	FMessageBridge (EAF70BF-4B99-77AB-9D76-A0D9)
[-]	[-]	FMessageBridge (9D5D37FA-4B03-1046-4541-098BF)
[-]	[-]	FMessageBridge (26636488-4FCE-C43A-5969-BAB1E)
[-]	[-]	FMessageBridge (A603E3D1-4241-7942-688B-1699D)
[-]	[-]	FMessageBridge (A1A4B198-4617-039D-4133-E61C4)
[-]	[-]	FMessageBridge (517A7A15-40A9-6CC1-1B09-7D977)
[-]	[-]	FMessageBridge (A0F6A70-4D6C-E8A1-50A5-0F36)
[-]	[-]	FMessageBridge (F054F424-437C-11CD-E65C-7485D)
[-]	[-]	FMessageBridge (3EABE7D2-47FB-8BAA-69AE-F38B5)
[-]	[-]	FMessageBridge (DFAE1CB0-419F-A636-290A-2AA92)
[-]	[-]	FMessageBridge (436EA900-48A4-5125-4831-989224)
[-]	[-]	FMessageBridge (9EFD0941-4952-52AC-DE40-E98D)
[-]	[-]	FMessageBridge (80CC4672-4EE1-4711-91F3-DF89D)
[-]	[-]	FMessageBridge (CE8199C9-4AD9-7008-3E9A-28499)
[-]	[-]	FMessageBridge (90D01E20-47AA-BFB6-C3DC-969EC)
[-]	[-]	FMessageBridge (61FDCBEE-49F3-99F0-3419-0702A)
[-]	[-]	FMessageBridge (2AD0D079-48FC-DC7B-3A17-4A84D)
[-]	[-]	FMessageBridge (0963CFD4-4B41-6A26-5FA9-FDAD4)

Endpoint Data

Inspectors



Time Sent	Message Type	Routing Latency	Dispatch Latency	Handle Time
2013.05.03-20:44:57	EngineServicePing	25.7 us	-	-
2013.05.03-20:44:57	SessionServicePing	40.6 us	-	-
2013.05.03-20:43:37	SessionServicePing	32.7 us	-	-
2013.05.03-20:43:37	TargetDeviceServicePing	0.2 ms	-	-
2013.05.03-20:43:37	TargetDeviceServicePing	0.2 ms	-	-
2013.05.03-20:43:37	EngineServicePing	47.1 us	-	-
2013.05.03-20:43:37	TargetDeviceServicePing	0.2 ms	-	-
2013.05.03-20:43:38	SessionServicePing	31.3 us	-	-
2013.05.03-20:43:38	TargetDeviceServicePing	0.2 ms	-	-
2013.05.03-20:43:37	EngineServicePing	44.3 us	-	-
2013.05.03-20:43:38	TargetDeviceServicePing	0.2 ms	-	-
2013.05.03-20:43:37	SessionServicePing	38.0 us	-	-
2013.05.03-20:44:56	SessionServicePing	32.2 us	-	-
2013.05.03-20:43:37	TargetDeviceServicePing	0.2 ms	-	-
2013.05.03-20:43:37	TargetDeviceServicePing	0.2 ms	-	-
2013.05.03-20:43:38	EngineServicePing	44.8 us	-	-
2013.05.03-20:43:37	SessionServicePing	32.2 us	-	-
2013.05.03-20:43:37	TargetDeviceServicePing	0.2 ms	-	-
2013.05.03-20:44:56	TargetDeviceServicePing	0.2 ms	-	-
2013.05.03-20:43:37	TargetDeviceServicePing	0.2 ms	-	-
2013.05.03-20:43:37	TargetDeviceServicePing	0.2 ms	-	-
2013.05.03-20:43:37	TargetDeviceServicePing	0.2 ms	-	-
2013.05.03-20:44:56	EngineServicePing	52.3 us	-	-
2013.05.03-20:43:37	TargetDeviceServicePing	0.2 ms	-	-
2013.05.03-20:43:37	EngineServicePing	52.3 us	-	-
2013.05.03-20:43:37	EngineServicePing	23.3 us	-	-
2013.05.03-20:43:37	SessionServicePing	29.0 us	-	-
2013.05.03-20:43:37	TargetDeviceServicePing	0.2 ms	-	-
2013.05.03-20:43:37	TargetDeviceServicePing	0.2 ms	-	-
2013.05.03-20:43:37	TargetDeviceServicePing	0.2 ms	-	-
2013.05.03-20:43:37	EngineServicePing	45.7 us	-	-
2013.05.03-20:43:37	EngineServicePing	22.4 us	-	-
2013.05.03-20:43:37	EngineServicePing	23.3 us	-	-
2013.05.03-20:44:56	EngineServicePing	23.8 us	-	-
2013.05.03-20:43:37	SessionServicePing	30.3 us	-	-
2013.05.03-20:43:37	TargetDeviceServicePing	0.2 ms	-	-
2013.05.03-20:43:37	TargetDeviceServicePing	0.2 ms	-	-
2013.05.03-20:43:37	TargetDeviceServicePing	0.2 ms	-	-
2013.05.03-20:43:36	EngineServicePing	48.5 us	-	-

213 messages

Breakpoints

Name Hit Count

Message Types

Message Type Filter

Name

Messages

[-]	[-]	EngineServicePing	6
[-]	[-]	SessionServicePing	6
[-]	[-]	TargetDeviceServicePing	4
[-]	[-]	SessionServicePing	42
[-]	[-]	TargetDeviceServicePing	98
[-]	[-]	EngineServicePing	49
[-]	[-]	IOSLaunchDaemonPing	8

Message Data

Upcoming Features

Critical sections & events

- Better debugging and profiling support

Task Graph

- Improvements and optimizations

UObjects

- Thread-safe construction and destruction

Parallel Rendering

- Implemented inside renderers, not on RHI API level

Messaging

- UDP v2 (“Hammer”), BLOB attachments, more robust, breakpoints
- Named Pipes and other transport plug-ins

More lock-free containers

Questions?

Documentation, Tutorials and Help at:

- AnswerHub: <http://answers.unrealengine.com>
- Engine Documentation: <http://docs.unrealengine.com>
- Official Forums: <http://forums.unrealengine.com>
- Community Wiki: <http://wiki.unrealengine.com>
- YouTube Videos: <http://www.youtube.com/user/UnrealDevelopmentKit>
- Community IRC: #unrealengine on FreeNode

Unreal Engine 4 Roadmap

- imgtfy.com/?q=Unreal+engine+Trello+

