



Investigating memory leaks



Memory Leaking Code

```
void OnStart()
    timer1 = new System.Threading.Timer((arg) => {
         String str = prefixTime + System.DateTime.Now.ToString();
                                                             There is subtle memory leak in this
         callListener += (bool isResume) =>
                                                              code. Managed memory profiler
                                                                helps us to find leak here.
              label.Text = (isResume ? prefixResume : prefixSleep) + str;
         };
     }, null, 0, 1);
```

Why another profiler?

- Native profilers
 - Where is unmanaged memory allocated?
- Managed profilers
 - What's managed memory used for and where is it allocated?
- All profilers:
 - How much memory is used by the application?

Questions:

- What about applications with mixed managed and unmanaged code?
- How much *physical* memory is used by the application?

Mixed code

In mixed applications, native memory lifetime can be determined by managed code.



- What happens when a managed object is collected, but doesn't free native memory?
 - Managed memory profilers show no leaks
 - Native profilers detect a memory leak, but don't provide enough information to eliminate it

Virtual / physical memory

- Memory allocated using standard library and system calls is not application's physical memory usage.
- Physical memory is allocated when the memory is written to (copy-on-write)
- Memory can be shared with other processes



Memory Profilers

There are a number of memory profiler tools already available

	Tashpalagy	mallaa	managed (NET)	mmap/munmap			
	rechnology	manoc	Inanayeu (.NET)	<u>virtual</u>	physical		
dotMemory	.NET Profiling API	-	+	-	-		
Valgrind (Massif)	Binary translation (slow)	+	-	+	-		
Tizen .NET Memory Profiler		+	+	+	+		
KDE HeapTrack		+	-	-	-		
Dynamic Analyzer (based on LeakSanitizer)	Symbol interception (fast)	+	-	-	-		
MemProf		+	-	-	-		

- Tizen .NET Memory Profiler can track managed memory and physical memory consumption
- Tracking managed memory and physical memory consumption is crucial for figuring out and investigating memory leaks in .NET applications

Based on open-source KDE Heaptrack, extended to:

- Track managed objects
- Combine managed and native call stacks
- Make snapshots of a managed heap
- Show physical memory consumption







KDE Heaptrack architecture:

- A profiler library (tracker) is preloaded into an application, or injected during runtime
- Calls to malloc/calloc/realloc/free are intercepted by the library and sent to a trace encoder
- A compact trace is written to a hard drive by the trace encoder
- Trace analyzer is used by an expert to examine the trace



Tizen .NET Memory Profiler architecture:

- Managed profiler receives callbacks upon object allocation, GC start/stop, function enter/leave, object movement by GC, and forwards them to the tracker
- Tracker combines native and managed call stacks, providing complete call site data for both managed and native allocations, tracks managed object allocations, movements and deallocations in the heap
- Extended encoder writes managed allocations, call stacks and heap snapshots to the trace



- calls to mmap, mmap64, munmap are intercepted by the tracker and their call sites are recorded
- tracker periodically reads /proc/self/smaps.
 Whenever a new physically mapped (private dirty) region is found, a corresponding call site is located and the data is written to the trace



Memory Leaking Code (example 1)

```
void OnStart()
    timer1 = new System.Threading.Timer((arg) => {
         String str = prefixTime + System.DateTime.Now.ToString();
                                                              There is unnoticeable memory leak
         callListener += (bool isResume) =>
                                                              issue in this code. Managed memory
                                                               profiler helps us to find leak here.
              label.Text = (isResume ? prefixResume : prefixSleep) + str;
         };
     }, null, 0, 1);
```

Managed memory consumption chart



Memory Leaking Code (example 2)

class Graph : System.IDisposable

```
private int w, h;
```

```
[System.Runtime.InteropServices.DllImport("native-graphics.so", EntryPoint = "Draw")]
    static extern void Draw(int width, int height);
    [System.Runtime.InteropServices.DllImport("native-graphics.so, tryPoint = "FreeMemory")]
    static extern void FreeMemory();
                                                                              The unmanaged memory is allocated by
    public Graph(int width, int height) { w = width; h = height; }
                                                                              the `malloc` in unmanaged code called
    public void DrawPicture() { Draw(w, h); }
                                                                                       from DrawPicture
    public void Dispose() { FreeMemory(); }
}
void OnDraw()
                                                                           It should be freed here by calling Dispose
                                                                                        method
    Graph graph = new Graph(this.width, this.height);
                                    Because the Dispose method is not called, unmanaged
    graph.DrawPicture();
                                            memory is never freed in this case
    // graph.Dispose is not called; and `using` construction is not used also
}
```

Managed memory consumption



Unmanaged memory consumption



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Call stacks for memory allocations

This chart shows us where exactly the leaking allocation came from



2.9 MB (83.5%) contribution to peak consumption in malloc and below.

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Summary

- The Tizen .NET Memory Profiler is prototype memory profiling solution that is capable of providing the baseline necessary information for detecting and investigating memory leaks in .NET applications
- Key features:
 - Track managed and unmanaged memory
 - Track physical memory consumption
- The solution is based on KDE HeapTrack, which is fast and stable project with more than four-years history

Short-term plans

- Add more descriptive information about location in managed code
 - Display file names and line numbers where possible
 - Display function argument lists
 - Improve profiling performance
 - Current performance slowdown is ~20-100x compared to running without profiler.

THANK YOU! 감사합니다! СПАСИБО!



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Heap snapshot

Instances	Shallow Size 🗕	Referenced Si:	Class Name
▼ 3378	116.4 KB	3.1 MB	[System.String]
▼ 2867	44.8 KB	2.6 MB	[XamarinApplication.ClockView]
▼ 1	16.0 KB	2.6 MB	[XamarinApplication.ClockView[]]
▼ 1	24 B	2.6 MB	[System.Collections.Generic.List`1]
▼ 1	16 B	910.1 KB	[XamarinApplication.ClockModel]
▼ 1	16 B	260.0 KB	[XamarinApplication.App]
1	0 B	260.0 KB	<gcroot></gcroot>
1	0 B	650.0 KB	<gcroot></gcroot>
1	0 B	1.7 MB	<gcroot></gcroot>
▼ 1	16 B	96 B	[XamarinApplication.App]
1	0 B	96 B	<gcroot></gcroot>
1	0 B	136 B	<gcroot></gcroot>
▶ 3	5.5 KB	13.6 KB	[System.Object[]]
▼ 186	2.2 KB	452.9 KB	[XamarinApplication.Label]
▼ 186	2.9 KB	452.9 KB	[XamarinApplication.ClockView]
▼ 1	16.0 KB	452.9 KB	[XamarinApplication.ClockView[]]
▼ 1	24 B	452.9 KB	[System.Collections.Generic.List`1]
▶ 1	16 B	154.7 KB	[XamarinApplication.ClockModel]
1	0 B	298.3 KB	<gcroot></gcroot>

Managed memory by type

File Summary Bottom-Up Caller / Callee Top-Down Managed Heap File Consumed Instances Allocated Sizes Stacks Selected Stack 1 / 63 Selected Stack Selected Stack 1 / 63 Selected Stack		Heaptrack - res.gz — Heaptrack GUI										8		
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> 576 B 20 576 B 25 836 B [System.String[]] in ?? () > 576 B 12 576 B [Xamarin.Forms.Style] in ?? () > 552 B 46 552 B [System.IntPtr] in ?? () > 480 B 15 480 B [System.String[]] + ?? () > 480 B 30 480 B [System.IntPtr] in ?? () > 480 B 30 480 B [System.Collections.Generic.Dictionary'2.Entry[]]~4 in ?? () > 488 B 3 468 B [System.Collections.Generic.Dictionary'2.Entry[]]~8 in ?? () > 488 B 3 468 B [System.Collections.Generic.Dictionary'2.Entry[]] ~8 in ?? () > 428 B 5 428 B 7 548 B [System.Collections.Generic.Dictionary'2.Entry[]] ~8 in ?? () > 364 B 9 364 B 9 364 B [ElmSharp.SmattEvent'1.NativeCallback[] in ?? ()	▶ 648 B	7	648 B	7	648 B	[System.C	ollections.Gen	eric.HashSet`	1.Slot[]] in ?? ()					
> 576 B 12 576 B [Xamarin.Forms.Style] in ?? () > 552 B 46 552 B 46 552 B [System.IntPtr] in ?? () > 480 B 15 480 B 15 480 B [System.EventHandler] in ?? () > 480 B 30 480 B 30 480 B [System.Collections.Generic.Dictionary'2.Entry[]]~4 in ?? () > 468 B 3 468 B 3 468 B [System.Collections.Generic.Dictionary'2.Entry[]]~8 in ?? () > 468 B 3 468 B 3 468 B [System.Collections.Generic.Dictionary'2.Entry[]]~8 in ?? () > 428 B 5 428 B 7 548 B [System.Collections.Generic.Dictionary'2.Entry[]] in ?? () > 364 B 9 364 B 9 364 B [ElmSharp.SmattEvent'1.NativeCallback[]] in ?? ()	▶ 576 B	20	576 B	25	836 B	[System.St	ring[]] in ?? ()							
> 552 B 46 552 B [System.IntPtr] in ?? () > 480 B 15 480 B [System.EventHandler] in ?? () > 480 B 30 480 B 15 480 B > 480 B 30 480 B [System.EventHandler] in ?? () > 480 B 30 480 B [System.Collections.Generic.Dictionary`2.Entry[]]~4 in ?? () > 468 B 3 468 B [System.Collections.Generic.Dictionary`2.Entry[]]~8 in ?? () > 468 B 5 428 B 7 548 B [System.Collections.Generic.Dictionary`2.Entry[]]~8 in ?? () > 468 B 9 364 B [System.Collections.Generic.Dictionary`2.Entry[]] in ?? ()	576 B	12	576 B	12	576 B	[Xamarin.F	orms.Style] in	n ?? ()						
\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	▶ 552 B	46	552 B	46	552 B	[System.In	tPtr] in ?? ()							
\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	▶ 480 B	15	480 B	15	480 B	[System.E	/entHandler] i	n ?? ()						
> 468 B 3 468 B 3 468 B [System.Collections.Generic.Dictionary 2.Entry[]]~4 in ?? () > 468 B 3 468 B 3 468 B [System.Collections.Generic.Dictionary 2.Entry[]]~8 in ?? () > 428 B 5 428 B 7 548 B [System.Collections.Generic.Dictionary 2.Entry[]] ~8 in ?? () > 364 B 9 364 B 9 364 B [ElmSharp.SmartEvent 1.NativeCallback[]] in ?? ()	▶ 480 B	30	480 B	30	480 B	[Xamarin.F	orms.Platform	n.Tizen.Export	RendererAttribu	ite] in ?? ()				
468 B 3 468 B 3 468 B 3 468 B 3 468 B 5 428 B 5 428 B 7 548 B [System.Collections.Generic.Dictionary 2.Entry[]]~8 in ?? () 364 B 9 364 B () 4	▶ 468 B	3	468 B	3	468 B	[System.C	ollections.Gen	eric.Dictionar	y 2.Entry[]]~4 i	n 7? ()				
• 428 B • 5 • 428 B • 7 • 548 B [System.Collections.Generic.Dictionary 2.Entry[]] in ?? () • 364 B [EimSharp.SmartEvent 1.NativeCallback[]] in ?? () • • •	▶ 468 B	3	468 B	3	468 B	[System.C	ollections.Gen	eric.Dictionar	y 2.Entry[]]~8 i	n ?? ()				
> 364 B 9 364 B 9 364 B LEImSharp.SmartEvent 1.NativeCallback[J] in ?? ()	▶ 428 B	5	428 B	7	548 B	[System.C	ollections.Gen	eric.Dictionar	y 2.Entry[]] in ?	2.0				
	▶ 364 B	9	364 B	9	364 B	LEImSharp	SmartEvent	L.NativeCallba	CK[]] IN ?? ()			Ŧ		

Managed flame graph



256.7 KB contribution to peak consumption

Consumed managed memory



Samsung R&D Institute Russia