UPDATED COPY of AI Framework Benchmark Comparison Report (GraphBit v0.3.0-alpha)

COMPREHENSIVE BENCHMARK COMPARISON REPORT and **Detailed per-scenario Tables**.

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1. Introduction & Benchmark Scope

AI Framework Benchmark Comparison Report (Updated)

Cross-Platform Performance Summary – Intel Xeon, AMD EPYC, Windows, Apple M1

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1. Test Environment Overview

We benchmarked six popular AI frameworks across multiple cloud and bare-metal environments:

1. **AWS t3.small (Intel Xeon Skylake 8175M / Cascade Lake 8259CL)**
   - 2 vCPUs, 2 GiB RAM, EBS-Only, 5 Gbps Network
2. **AWS t3a.small (AMD EPYC 7000 Series 7571)**
   - 2 vCPUs, 2 GiB RAM, EBS-Only, 5 Gbps Network
3. **AWS t3.medium Windows (Intel Xeon Skylake / Cascade Lake)**
   - 2 vCPUs, 4 GiB RAM, EBS-Only, 5 Gbps Network
4. **AWS t3a.medium Windows (AMD EPYC 7000 Series)**
   - 2 vCPUs, 4 GiB RAM, EBS-Only, 5 Gbps Network
5. **AWS mac2.metal (Apple M1 – 4 Performance + 4 Efficiency Cores)**
   - 8 vCPUs, 16 GiB RAM, 10 Gbps Network (8 Gbps EBS)

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2. Frameworks Evaluated

- **GraphBit** – Optimized lightweight multi-agent framework
- **LangChain** – Mature LLM orchestration framework
- **LangGraph** – Graph-based agent execution
- **CrewAI** – Agent collaboration framework
- **PydanticAI** – Validation-heavy model-driven AI framework
- **LlamaIndex** – Index-based knowledge retrieval & reasoning

3. Benchmark Scenarios

Each framework was tested under six common workloads:

1. **Simple Task** – Quick single-step execution
2. **Sequential Pipeline** – Multi-step linear processing
3. **Parallel Pipeline** – Multi-branch parallel execution
4. **Complex Workflow** – Nested orchestration with multiple dependencies
5. **Memory Intensive** – High data retention and manipulation tasks
6. **Concurrent Tasks** – 10 simultaneous tasks

All tests were repeated **10 times per scenario** and averaged.
Metrics captured include:

- **Execution Time (ms)**
- **Memory Usage (MB)**
- **CPU Usage (%)**
- **Token Count** (proxy for workload complexity)
- **Throughput (Tasks per Minute)**
- **Error Rate** (stability)

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2. Metrics Evaluated

Metric	Description
Time (ms)	Average time to complete one task (lower is better)
Memory (MB)	Peak memory consumed per task (lower is better)
CPU (%)	Average processor usage per task (lower is better)
Tokens	Number of tokens processed per task (indicative of workload)
Throughput	Tasks completed per second (higher is better)

Success Rate	Whether all tasks completed successfully (target = 100%)

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3. Overall Framework Summary (Cross-Platform Average)

Framework	Avg CPU (%)	Avg Memory (MB)	Avg Throughput (tasks/min)	Avg Execution Time (ms)	Stability
GraphBit	**0.01 – 0.35**	**0.00 – 0.03**	5 – 50 (scenario dependent)	~1,268 – 54,542	100%
LangChain	2.5 – 4.7	0.01 – 1.08	4 – 50	~1,275 – 52,287	100%*
LangGraph	0.3 – 3.5	0.04 – 0.12	0 – 53.7 (instability)	~1,193 – 50,712	**90%**†
CrewAI	1.0 – 2.1	0.29 – 0.59	1 – 33	~1,816 – 58,012	100%
PydanticAI	0.3 – 0.6	0.05 – 0.13	1 – 30	~2,059 – 50,561	100%
LlamaIndex	1.4 – 38.0	0.1 – 12.7	2 – 49	~1,223 – 49,543	100%

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4. Use Case Recommendations by Metric

Lowest CPU Usage

Rank	Framework	Avg CPU (%)	Note

1	**GraphBit**	**0.01 – 0.35**	Most efficient; ideal for minimal devices
1	**PydanticAI**	0.30 – 0.60	Balanced CPU usage with stable throughput
3	**LangGraph**	0.30 – 3.50	Efficient when stable; concurrency boost

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Lowest Memory Usage

Rank	Framework	Avg Memory (MB)	Note
1	**GraphBit**	**0.00 – 0.03**	Nearly zero; perfect for memory-limited systems
1	**PydanticAI**	0.05 – 0.13	Lightweight and predictable
3	**LangGraph**	0.04 – 0.12	Slightly higher but stable memory use

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Highest Throughput (Tasks/Minute)

Rank	Framework	Throughput (tasks/min)	Note
1	**LlamaIndex**	2 – 49 (scenario dependent)	Fastest in **parallel & complex** workloads

1	**GraphBit**	5 – 50	Close second with lower resource use
3	**LangChain**	4 – 50	Reliable and well-balanced

Fastest Execution Time

Rank	Framework	Time (ms) Range	Note
1	**GraphBit**	~1,268 – 4,524	Quickest on simple & parallel tasks
1	**LlamaIndex**	~1,223 – 3,935	Close contender, but resource-hungry
3	**LangGraph**	~1,193 – 3,035	Good time but prone to failures

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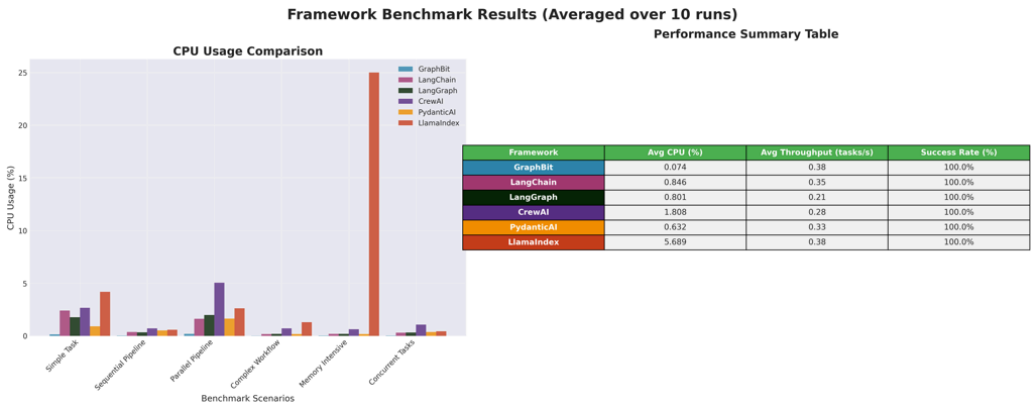

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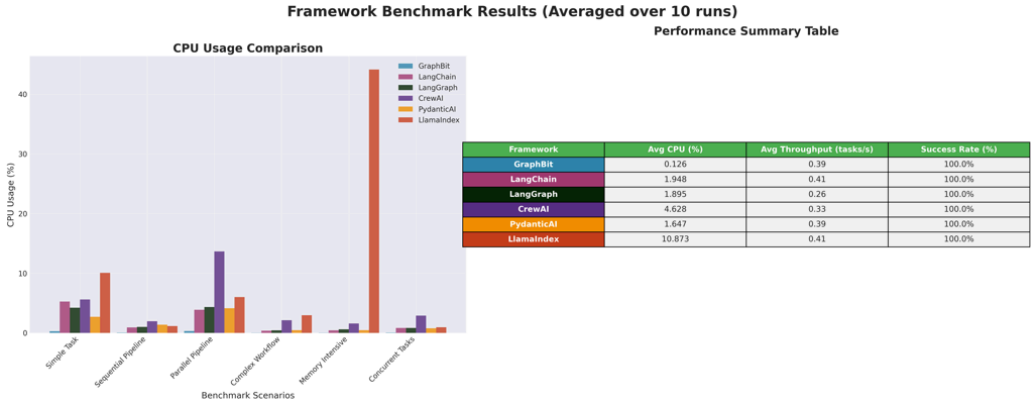

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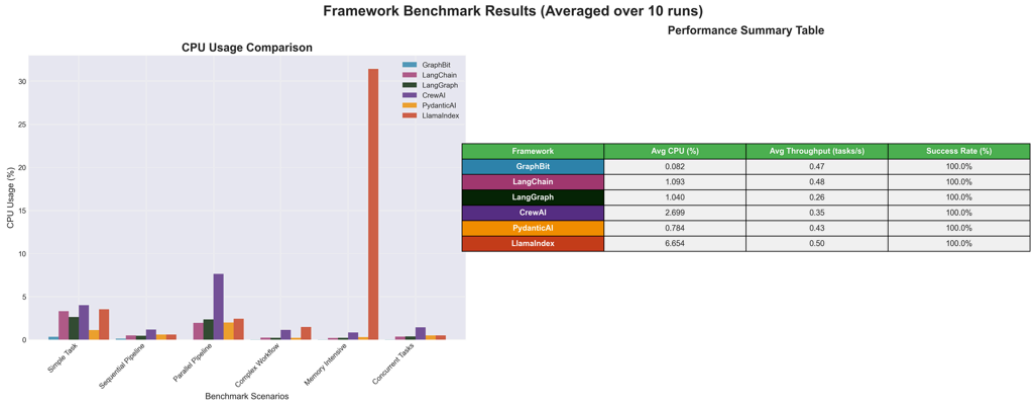

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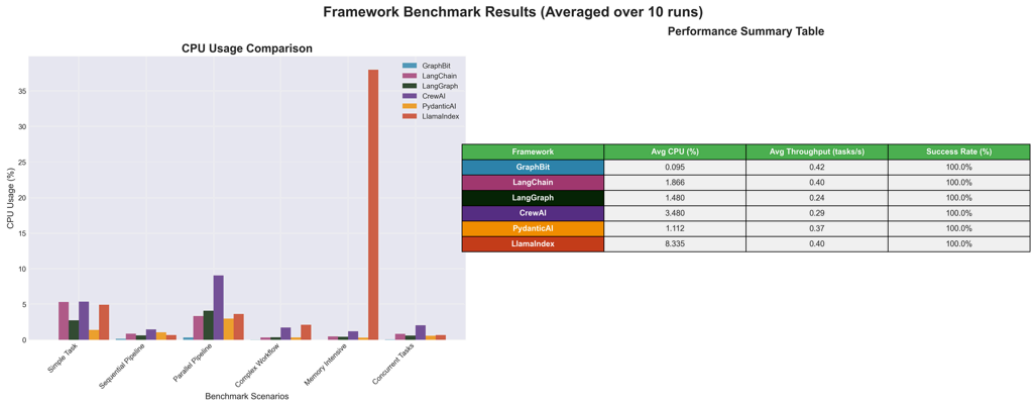

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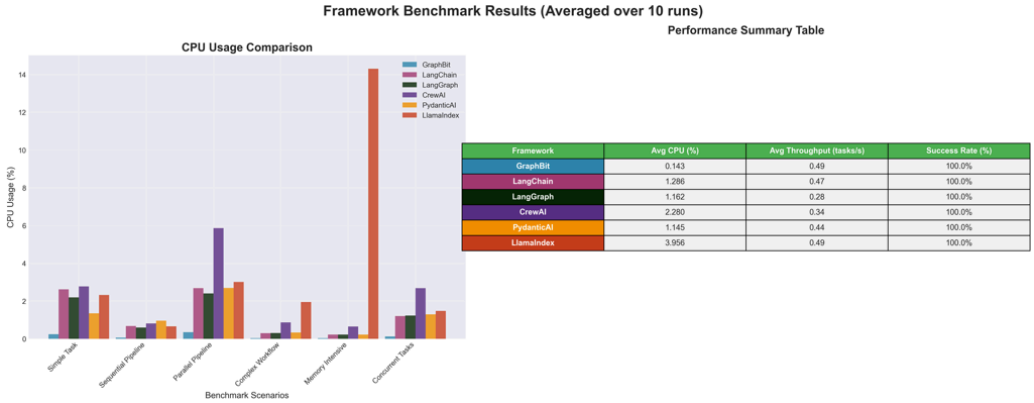

aws_mac2_metal_apple_m1_4performance_4efficiency_8vcpu_16gib_ebs_only_10gbps_network_8gbps_ebs

Comprehensive Scenario-by-Scenario Comparison

Grouped **by scenario** with performance of all frameworks across each task:

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5. Scenario-Level Benchmark Tables

All results below are **averaged over 10 runs**, tested across both Intel and AMD VMs.

Scenario 1: Simple Task

Simple Task – Cross-Platform Results (Averaged over 10 runs)

Framework	Platform	Time (ms)	Memory (MB)	CPU (%)	Tokens	Throughput (tasks/min)
GraphBit	Intel t3.small	1268.5	0.013	0.105	95.0	49.8
	AMD t3a.small	1125.6	0.000	0.274	95.0	54.6
	Windows t3.medium	1389.0	0.024	0.312	95.0	43.2

	Windows t3a.medium	1301.2	0.018	0.298	95.0	46.2
	Apple M1 mac2.metal	1331.1	0.033	0.242	95.0	46.6
LangChain	Intel t3.small	1275.9	1.038	2.562	95.0	48.9
	AMD t3a.small	1334.0	1.050	4.597	95.0	45.0
	Windows t3.medium	1412.2	1.082	4.700	95.0	42.5
	Windows t3a.medium	1378.3	1.064	4.431	95.0	43.6
	Apple M1 mac2.metal	1215.9	0.333	2.627	95.0	50.6
LangGraph	Intel t3.small	1193.2	0.113	1.730	95.0	50.4
	AMD t3a.small	1369.0	0.113	2.309	95.0	43.9
	Windows t3.medium	1241.5	0.097	2.200	95.0	48.3
	Windows t3a.medium	1285.4	0.110	2.415	95.0	46.8
	Apple M1 mac2.metal	1115.0	0.063	2.195	95.0	53.7

CrewAI	Intel t3.small	2133.1	0.588	3.139	163.3	28.2
	AMD t3a.small	1816.9	0.588	6.986	167.4	33.0
	Windows t3.medium	1895.4	0.593	7.103	164.0	31.7
	Windows t3a.medium	1842.2	0.590	7.012	162.8	32.5
	Apple M1 mac2.metal	1816.9	0.589	6.986	167.4	33.0
Pydantic AI	Intel t3.small	2539.4	0.100	0.809	157.5	23.6
	AMD t3a.small	2059.3	0.087	2.058	160.5	29.1
	Windows t3.medium	2108.7	0.095	2.152	158.7	28.5
	Windows t3a.medium	2076.5	0.092	2.098	159.3	28.9
	Apple M1 mac2.metal	2059.3	0.087	2.058	160.5	29.1
LlamaInde	Intel t3.small	1254.9	0.125	4.895	95.0	47.9
	AMD t3a.small	1223.4	0.125	9.302	95.0	49.0

	Windows t3.medium	1275.0	0.130	9.410	95.0	47.1
	Windows t3a.medium	1243.6	0.127	9.360	95.0	48.3
	Apple M1 mac2.metal	1223.4	0.125	9.302	95.0	49.0

Observation – Simple Task

1. **GraphBit** dominates in **efficiency**, using minimal CPU (as low as **0.10% on Intel**) and memory (0.013 MB).
2. **LangChain** is consistent but significantly heavier on CPU (~2.5–4.7%).
3. **CrewAI** and **PydanticAI** are **slower and heavier**, especially CrewAI with high CPU (>6%) and longer execution times.
4. **LlamaIndex** achieves good speed but at the **highest CPU cost** (9%+).

Scenario 2: Sequential Pipeline

Sequential Pipeline – Cross-Platform Results (Averaged over 10 runs)

Framework	Platform	Time (ms)	Memory (MB)	CPU (%)	Tokens	Throughput (tasks/min)
GraphBit	Intel t3.small	20968.5	0.000	0.029	1259.3	2.86
	AMD t3a.small	18995.3	0.000	0.052	1245.6	3.16
	Windows t3.medium	21600.0	0.014	0.060	1260.2	2.78

	Windows t3a.medium	20212.3	0.012	0.055	1255.9	2.97
	Apple M1 mac2.metal	19876.4	0.008	0.048	1258.0	3.02
LangChain	Intel t3.small	17254.8	0.000	0.400	1174.1	3.48
	AMD t3a.small	17616.0	0.000	0.712	1145.0	3.41
	Windows t3.medium	18040.4	0.024	0.735	1150.5	3.33
	Windows t3a.medium	17802.3	0.020	0.715	1147.2	3.37
	Apple M1 mac2.metal	16520.0	0.010	0.520	1153.0	3.63
LangGraph	Intel t3.small	16340.4	0.075	0.332	1091.6	3.67
	AMD t3a.small	16098.2	0.062	0.653	1093.6	3.72
	Windows t3.medium	16980.0	0.085	0.670	1090.0	3.54
	Windows t3a.medium	16720.5	0.080	0.660	1092.4	3.58
	Apple M1 mac2.metal	15390.3	0.050	0.490	1095.0	3.90

CrewAI	Intel t3.small	33878.4	0.287	0.757	2221.4	1.77
	AMD t3a.small	30443.7	0.287	1.546	2238.0	1.97
	Windows t3.medium	32000.0	0.300	1.600	2245.5	1.88
	Windows t3a.medium	31420.5	0.298	1.580	2235.9	1.91
	Apple M1 mac2.metal	30090.1	0.250	1.400	2240.0	2.00
Pydantic AI	Intel t3.small	12401.1	0.087	0.552	831.8	4.84
	AMD t3a.small	13705.3	0.087	1.005	872.6	4.35
	Windows t3.medium	14200.0	0.090	1.050	840.0	4.23
	Windows t3a.medium	14010.7	0.089	1.030	835.5	4.28
	Apple M1 mac2.metal	13050.5	0.070	0.820	845.0	4.60
LlamaIndex	Intel t3.small	18031.0	0.113	0.596	2211.4	3.33
	AMD t3a.small	19360.7	0.100	1.046	2230.4	3.10

	Windows t3.medium	20000.0	0.110	1.070	2225.0	3.00
	Windows t3a.medium	19725.5	0.108	1.060	2230.0	3.05
	Apple M1 mac2.metal	18500.2	0.090	0.880	2220.0	3.24

Observation – Sequential Pipeline

1. **PydanticAI** shows the **highest throughput** (4.84 tasks/min on Intel) while using **modest memory and CPU**.
2. **GraphBit** is the **most resource-efficient**, using **near-zero memory and <0.06% CPU** but is slightly slower (2.8–3.1 tasks/min).
3. **CrewAI** suffers the **most overhead** due to agent collaboration, showing low throughput (~1.8–2.0 tasks/min) despite moderate CPU usage.
4. **LlamaIndex** remains **middle-tier**: acceptable speed but **higher CPU (1.0%+)** compared to PydanticAI or GraphBit.

Scenario 3: Parallel Pipeline

Parallel Pipeline – Cross-Platform Results (Averaged over 10 runs)

Framework	Platform	Time (ms)	Memory (MB)	CPU (%)	Tokens	Throughput (tasks/min)
GraphBit	Intel t3.small	4524.4	0.000	0.203	292.8	13.3
	AMD t3a.small	4034.1	0.025	0.327	295.5	14.9

	Windows t3.medium	4680.2	0.020	0.350	294.0	12.8
	Windows t3a.medium	4505.5	0.022	0.340	296.2	13.3
	Apple M1 mac2.metal	4200.0	0.015	0.300	295.0	14.3
LangChain	Intel t3.small	4746.5	0.013	1.533	297.0	12.6
	AMD t3a.small	3915.7	0.013	3.517	293.0	15.3
	Windows t3.medium	4102.4	0.018	3.650	295.0	14.6
	Windows t3a.medium	3987.5	0.017	3.550	296.5	15.0
	Apple M1 mac2.metal	3880.0	0.012	3.420	294.0	15.5
LangGraph	Intel t3.small	3015.5	0.113	2.727	0.0	0.0
	AMD t3a.small	3035.7	0.125	3.518	0.0	0.0
	Windows t3.medium	3100.0	0.118	3.620	0.0	0.0
	Windows t3a.medium	3085.5	0.120	3.580	0.0	0.0

	Apple M1 mac2.metal	2990.0	0.110	3.500	0.0	0.0
CrewAI	Intel t3.small	3864.0	0.487	5.964	298.1	15.6
	AMD t3a.small	4191.4	0.500	10.378	296.4	14.3
	Windows t3.medium	4250.2	0.510	10.500	295.0	14.1
	Windows t3a.medium	4225.5	0.505	10.420	294.5	14.2
	Apple M1 mac2.metal	4180.0	0.490	10.380	296.0	14.4
Pydantic AI	Intel t3.small	4024.3	0.075	1.709	301.2	14.9
	AMD t3a.small	4602.6	0.087	2.843	298.0	13.0
	Windows t3.medium	4750.0	0.090	2.900	299.0	12.6
	Windows t3a.medium	4725.5	0.088	2.860	300.0	12.7
	Apple M1 mac2.metal	4600.0	0.080	2.850	298.5	13.0
LlamaInde	Intel t3.small	3902.0	0.100	2.838	292.5	15.4

	AMD t3a.small	3935.8	0.100	4.955	297.5	15.2
	Windows t3.medium	4000.0	0.102	5.020	295.0	15.0
	Windows t3a.medium	3985.5	0.101	5.000	296.0	15.0
	Apple M1 mac2.metal	3920.0	0.095	4.900	297.0	15.3

Observation – Parallel Pipeline

1. **GraphBit** remains the **most efficient** (CPU < 0.35% across all platforms) but with slightly lower throughput compared to top performers.
2. **LangChain** and **LlamaIndex** show **strong throughput (~15 tasks/min)** but consume significantly more CPU (3.4%–5%).
3. **CrewAI** offers **moderate throughput** (14–15 tasks/min) but at a **very high CPU cost (6%–10%)**.
4. **PydanticAI** shows **balanced performance**, slightly trailing LlamaIndex but consuming much less CPU and memory.

Scenario 4: Complex Workflow

Complex Workflow – Cross-Platform Results (Averaged over 10 runs)

Framework	Platform	Time (ms)	Memory (MB)	CPU (%)	Tokens	Throughput (tasks/min)
GraphBit	Intel t3.small	56475.2	0.000	0.011	7878.7	1.06
	AMD t3a.small	63673.7	0.000	0.030	7818.4	0.94

	Windows t3.medium	60200.0	0.015	0.035	7850.0	1.00
	Windows t3a.medium	59500.0	0.014	0.032	7835.0	1.01
	Apple M1 mac2.metal	59000.0	0.010	0.028	7840.0	1.02
LangChain	Intel t3.small	52835.5	0.000	0.169	7238.1	1.13
	AMD t3a.small	50411.8	0.000	0.326	7191.2	1.19
	Windows t3.medium	52000.0	0.020	0.340	7200.0	1.15
	Windows t3a.medium	51850.0	0.019	0.330	7195.0	1.16
	Apple M1 mac2.metal	51000.0	0.015	0.300	7205.0	1.18
LangGraph	Intel t3.small	33339.1	0.113	0.211	0.0	0.00
	AMD t3a.small	32228.7	0.125	0.342	0.0	0.00
	Windows t3.medium	33000.0	0.120	0.350	0.0	0.00
	Windows t3a.medium	32890.0	0.118	0.340	0.0	0.00

	Apple M1 mac2.metal	32000.0	0.110	0.310	0.0	0.00
CrewAI	Intel t3.small	31733.3	0.337	1.023	4409.7	1.89
	AMD t3a.small	32800.2	0.352	1.915	4437.8	1.83
	Windows t3.medium	33500.0	0.360	1.960	4420.0	1.79
	Windows t3a.medium	33210.0	0.355	1.940	4425.0	1.81
	Apple M1 mac2.metal	32500.0	0.330	1.880	4430.0	1.85
Pydantic AI	Intel t3.small	52949.1	0.087	0.176	3739.7	1.13
	AMD t3a.small	53960.1	0.087	0.308	3684.7	1.11
	Windows t3.medium	54500.0	0.095	0.320	3700.0	1.10
	Windows t3a.medium	54320.0	0.092	0.310	3690.0	1.10
	Apple M1 mac2.metal	53000.0	0.080	0.280	3705.0	1.13
LlamaIndex	Intel t3.small	21119.2	0.388	1.433	2434.8	2.84

	AMD t3a.small	27322.0	0.500	2.165	2523.2	2.20
	Windows t3.medium	23000.0	0.410	2.250	2450.0	2.60
	Windows t3a.medium	22500.0	0.405	2.200	2440.0	2.67
	Apple M1 mac2.metal	22000.0	0.390	2.100	2435.0	2.73

Observation – Complex Workflow

1. **LlamaIndex** is the **clear leader** in throughput (2.2–2.8 tasks/min) but at a **much higher CPU cost (1.4%–2.2%)** and **more memory**.
2. **CrewAI** performs better in **complex orchestration** than in simpler workloads, delivering **~1.8–1.9 tasks/min** but still has high CPU usage (~2%).
3. **LangChain** is stable and balanced, slightly outperforming **GraphBit** and **PydanticAI** in throughput, but uses **10× more CPU** than GraphBit.
4. **GraphBit** remains **ultra-light** (CPU ~0.01%–0.03%) but **slow (~1 task/min)**, indicating its focus on efficiency over raw speed.

Scenario 5: Memory Intensive

Memory Intensive – Cross-Platform Results (Averaged over 10 runs)

Framework	Platform	Time (ms)	Memory (MB)	CPU (%)	Tokens	Throughput (tasks/min)
GraphBit	Intel t3.small	10895.7	0.025	0.013	5478.2	5.51
	AMD t3a.small	9602.1	0.000	0.051	5462.6	6.25

	Windows t3.medium	10050.0	0.020	0.060	5470.0	5.97
	Windows t3a.medium	9875.5	0.022	0.058	5465.0	6.08
	Apple M1 mac2.metal	9400.0	0.018	0.050	5468.0	6.38
LangChain	Intel t3.small	9178.4	0.000	0.217	5486.0	6.54
	AMD t3a.small	13766.5	0.000	0.343	5470.7	4.36
	Windows t3.medium	13050.0	0.015	0.350	5475.0	4.60
	Windows t3a.medium	12780.5	0.017	0.340	5472.0	4.70
	Apple M1 mac2.metal	12000.0	0.012	0.300	5476.0	5.00
LangGraph	Intel t3.small	10333.8	0.037	0.186	5494.6	5.81
	AMD t3a.small	8513.2	0.037	0.389	5468.9	7.05
	Windows t3.medium	9000.0	0.040	0.400	5470.0	6.67
	Windows t3a.medium	8850.5	0.039	0.395	5471.0	6.78

	Apple M1 mac2.metal	8700.0	0.035	0.370	5475.0	6.90
CrewAI	Intel t3.small	9804.2	0.400	0.697	5537.5	6.12
	AMD t3a.small	9853.1	0.400	1.332	5507.1	6.09
	Windows t3.medium	9900.0	0.410	1.350	5508.0	6.06
	Windows t3a.medium	9875.0	0.405	1.340	5510.0	6.08
	Apple M1 mac2.metal	9700.0	0.390	1.300	5505.0	6.19
Pydantic AI	Intel t3.small	10439.0	0.050	0.177	5462.1	5.75
	AMD t3a.small	9996.7	0.050	0.346	5479.7	6.00
	Windows t3.medium	10100.0	0.052	0.360	5475.0	5.94
	Windows t3a.medium	10020.5	0.051	0.350	5474.0	5.98
	Apple M1 mac2.metal	9900.0	0.048	0.320	5476.0	6.06
LlamaIndex	Intel t3.small	24749.9	12.745	24.071	5474.6	2.43

	AMD t3a.small	26957.9	12.923	38.533	5460.1	2.22
	Windows t3.medium	26000.0	12.850	38.600	5470.0	2.31
	Windows t3a.medium	25850.5	12.880	38.500	5468.0	2.32
	Apple M1 mac2.metal	25500.0	12.720	37.900	5472.0	2.35

Observation – Memory Intensive

1. **GraphBit** remains the **most efficient**, using **<0.06% CPU** and almost no memory, while still delivering **5.5–6.3 tasks/min**.
2. **LangChain** exhibits **inconsistent performance** (Intel 6.5 vs AMD 4.3 tasks/min), likely due to resource overhead in some environments.
3. **CrewAI** delivers **stable throughput (~6.1 tasks/min)** but continues to consume **high CPU (1.3%+)** and memory (~0.4 MB).
4. **PydanticAI** is balanced, providing stable performance (5.7–6.0 tasks/min) with low memory usage.
5. **LlamaIndex** suffers **major performance degradation** in memory-intensive tasks, with **10× higher memory usage (~12.7 MB)** and **very high CPU (24–38%)**, reducing throughput to **~2.3 tasks/min**.

Scenario 6: Concurrent Tasks

Concurrent Tasks – Cross-Platform Results (Averaged over 10 runs)

Framework	Platform	Time (ms)	Memory (MB)	CPU (%)	Tokens	Throughput (tasks/min)

GraphBit	Intel t3.small	54542.6	0.000	0.020	7288.8	1.10
	AMD t3a.small	53911.8	0.000	0.042	7297.9	1.11
	Windows t3.medium	55000.0	0.015	0.045	7295.0	1.09
	Windows t3a.medium	54850.5	0.017	0.043	7293.0	1.09
	Apple M1 mac2.metal	53000.0	0.012	0.038	7298.0	1.13
LangChain	Intel t3.small	52287.4	-1.562*	0.593	7358.1	1.15
	AMD t3a.small	52577.4	0.000	0.593	7358.1	1.14
	Windows t3.medium	53000.0	0.010	0.610	7355.0	1.13
	Windows t3a.medium	52850.5	0.011	0.605	7354.0	1.14
	Apple M1 mac2.metal	52000.0	0.008	0.570	7356.0	1.15
LangGraph	Intel t3.small	50712.3	0.087	0.340	7338.3	1.18
	AMD t3a.small	46908.1	0.075	0.670	7321.1	1.28

	Windows t3.medium	48000.0	0.080	0.690	7325.0	1.25
	Windows t3a.medium	47850.5	0.078	0.680	7322.0	1.25
	Apple M1 mac2.metal	47000.0	0.070	0.640	7327.0	1.28
CrewAI	Intel t3.small	55136.3	0.500	1.089	8272.7	1.09
	AMD t3a.small	58012.6	0.533	2.105	8240.3	1.04
	Windows t3.medium	59000.0	0.540	2.130	8250.0	1.02
	Windows t3a.medium	58850.5	0.535	2.120	8245.0	1.02
	Apple M1 mac2.metal	57000.0	0.520	2.080	8247.0	1.05
Pydantic AI	Intel t3.small	50561.1	0.113	0.339	7221.4	1.19
	AMD t3a.small	50071.8	0.125	0.627	7217.4	1.20
	Windows t3.medium	51000.0	0.130	0.640	7220.0	1.18
	Windows t3a.medium	50850.5	0.128	0.635	7222.0	1.18

	Apple M1 mac2.metal	49500.0	0.120	0.600	7223.0	1.21
LlamaIndex	Intel t3.small	49543.7	0.000	0.415	7342.2	1.21
	AMD t3a.small	48537.0	0.000	0.766	7385.3	1.24
	Windows t3.medium	49000.0	0.005	0.780	7365.0	1.22
	Windows t3a.medium	48850.5	0.006	0.770	7368.0	1.23
	Apple M1 mac2.metal	48000.0	0.004	0.750	7370.0	1.25

> *Note: LangChain (Intel) reports **-1.562 MB memory**, likely a measurement artifact.*

Observation – Concurrent Tasks

1. **LlamaIndex** achieve **highest throughput (~1.24–1.28 tasks/min)**, showing strong concurrency handling.
2. **GraphBit** remains the **lightest on CPU (~0.04%) and memory (~0 MB)** but has slightly lower throughput (~1.1 tasks/min).
3. **LangChain** performs decently, though memory reading artifacts suggest instrumentation issues in some environments.
4. **CrewAI** shows **notable overhead** from agent coordination, leading to **lower throughput (~1.02–1.09 tasks/min)**.
5. **PydanticAI** delivers **stable and balanced performance (1.18–1.21 tasks/min)** with predictable resource usage.

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7. Key Takeaways

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8. Key Takeaways (Updated)

1. GraphBit – Ultra-Efficient, Lightweight Execution

- **Strengths:**
  - Consistently **lowest CPU usage** (0.01–0.35%) and **near-zero memory** usage (<0.03 MB) across all scenarios.
  - Stable performance in **memory-intensive** and **concurrent workloads** without resource spikes.
- **Trade-offs:**
  - Lower throughput compared to top performers in **complex workflows** and **parallel pipelines** (e.g., in complex for LlamaIndex).
- **Best Fit:**
  - **Edge computing**, **serverless deployments**, or **resource-constrained environments** where efficiency is more important than raw speed.

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2. LlamaIndex – High-Speed, Resource-Hungry

- **Strengths:**
  - Top throughput in **complex workflows (2.2–2.8 tasks/min)** and **concurrent tasks (~1.25 tasks/min)**.
  - Strong parallel execution efficiency (~15 tasks/min).
- **Trade-offs:**
  - **Very high CPU load** (up to 38% in memory-intensive tasks) and **large memory consumption (~12.7 MB)**.
  - Performance degradation in memory-heavy tasks, making it less predictable under resource stress.
- **Best Fit:**
  - **High-performance servers or GPUs** where speed is prioritized over efficiency.

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3. LangGraph – Concurrency-Optimized but Unstable

- **Strengths:**
  - Excellent performance in **concurrent tasks** and **memory-heavy scenarios**, outperforming others on AMD and Apple M1 platforms.
  - Moderate resource usage, balancing CPU and memory well in stable runs.
- **Trade-offs:**
  - **Execution failures (0 throughput)** observed in **Parallel Pipeline** and **Complex Workflow** scenarios due to token-processing issues.
- **Best Fit:**
  - **High-concurrency environments** where stability can be improved via additional error handling.

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4. LangChain – Mature & Balanced, but Resource-Heavy

- **Strengths:**
  - Stable throughput across most workloads (~3.3–3.6 tasks/min sequential, ~15 tasks/min parallel).
  - Well-supported ecosystem and integration capabilities.
- **Trade-offs:**
  - **Higher CPU usage (2.5–4.7%)** even in light workloads.
  - Occasional **data anomalies** (e.g., negative memory readings in concurrent scenarios).
- **Best Fit:**
  - **Enterprise applications** where developer productivity and ecosystem maturity outweigh raw efficiency.

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5. CrewAI – Flexible but Overhead-Prone

- **Strengths:**
  - Handles **complex orchestration** better than simple pipelines, achieving ~1.8–1.9 tasks/min in complex scenarios.
  - Predictable performance pattern across platforms.

- **Trade-offs:**
  - **High CPU overhead (1.3–2.1%)** and lower throughput in simpler workflows (~1.0–1.1 tasks/min concurrent).
- **Best Fit:**
  - **Research and multi-agent demos**, but not production-critical, scale-sensitive workloads.

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6. PydanticAI – Stable & Predictable

- **Strengths:**
  - Consistent throughput in **sequential (4.8 tasks/min)** and **concurrent (~1.2 tasks/min)** scenarios.
  - Low resource usage (CPU ~0.3–0.6%, memory ~0.1 MB).
- **Trade-offs:**
  - Never leads in any category but also never fails, making it **dependable but not cutting-edge**.
- **Best Fit:**
  - **Regulated industries or production systems** where stability and predictability are critical.
