Multi-objective Sparrow Search Optimization for Task Scheduling Problem in Fog-Cloud-Blockchain Systems

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1 Experimental Setup

In our experiments, we simulated the FCB system with 2 cloud nodes, 8 fog nodes, and 5 blockchain nodes. Due to the different resource capability, the fog, cloud and blockchain nodes have diverse configurations and parameters. The node characteristics (e.g., data generation, age of data, power consumption) is generated randomly in the value ranges. We refer these ranges from some websites such as [1] and [2] and some prior works [1–3].

We also consider two state types for the fog and cloud nodes include idle and running, which comply with the practical operation of a fog-cloud system. For the blockchain network, we also consider two state types including standby and running mode. Standby mode occurs when blockchain node is waiting for data transfer from the fog or cloud node (while still runs other tasks in the background such as hashing, verifying, and transferring transactions to other nodes). Running mode occurs when the blockchain node receives data, verify, transfer transactions, and storing data. The lifetime of data stored on fog nodes is denoted by parameter τ which is defined randomly in the [5, 20] range.

We generated ten datasets covering from 50 to 500 tasks in order to test the simulated FCB system. Our goal is to find the optimal scheduling plan, which optimizes power consumption, service latency, and monetary cost simultaneously. We compare our proposed optimizer MO-SSA against NSGA-II, NSGA-III, and the recent developed MO-ALO. With each algorithm, we set the maximum number of generations is 100 and the population size is 50. The maximum archive size is also 50. In the case of NSGA-II and NSGA-III, the crossover rate is 0.9, the mutation rate is 0.05. The MO-ALO does not need any other parameter. Finally, with MO-SSA, we set $ST = 0.8$, $RD = 0.1$.

2 Coefficient of Variation: The Additional Test

Algorithm's stability is also a good aspect to be considered. Therefore, we record the CV 10 different trials for each test case and each model in Table 2. According to Table. 2, the CV results of MO-SSA dominate all other algorithms in metrics ER and STE in large-scale tasks, meaning its results after 10 trials dispersed around the mean value are lower than others. Especially, for some tasks such as 250, 300 and 500, the CV results of MO-SSA is better than other algorithms in most metrics. In general, our proposed algorithm is completely competitive with other algorithms in the model's stability aspect.

References

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[1] http://cloudharmony.com/speedtest-for-aws:ec2
[2] https://www.datamation.com/cloud-computing/cloud-costs.html

Table 1: Environmental setup

	Parameter	**Notation**	**Value range**	**Unit**
Task	Data processed on fog nodes	R_p^T R_s^T	$[5*10^4, 5*10^5]$	byte
	Data processed on cloud nodes	Q_p^T Q_r^T	$[5*10^4, 5*10^5]$	
Blockchain Node	Power consumption for data forwarding	α^{BC} α_{sm}^{BC}	$[5*10^{-10}, 5*10^{-9}]$ $[100, 250]$	W/byte W
	Power consumption for storage	γ^{BC} γ_{sm}^{BC}	$[5*10^{-10}, 5*10^{-8}]$ $[50, 200]$	W/byte W
	Cost for data forwarding	σ^{BC} σ_{sm}^{BC}	$[5*10^{-10}, 5*10^{-8}]$ $[0.01, 0.1]$	$/byte $/s
	Cost for storage	ω^{BC} ω_{sm}^{BC}	$[10^{-16}, 10^{-14}]$ $[10^{-8}, 10*10^{-7}]$	$/byte $/s
Fog	Power consumption for data forwarding	α^{FG} α_{idle}^{FG}	$[5*10^{-8}, 5*10^{-6}]$ $[25, 100]$	W/byte W
	Power consumption for computation	β^{FG} β_{idle}^{FG}	$[5*10^{-7}, 5*10^{-5}]$ $[100, 500]$	W/byte W
	Power consumption for storage	γ^{FG} γ_{idle}^{FG}	$[5*10^{-7}, 5*10^{-5}]$ $[10, 50]$	W/byte W
	Delay of transmission	δ_{df}^{FG}	$[5*10^{-7}, 5*10^{-6}]$	s/byte
	Delay of processing	λ^{FG}	$[10^{-7}, 10^{-6}]$	
	Cost for data forwarding	σ^{FG} σ_{idle}^{FG}	$[5*10^{-9}, 5*10^{-8}]$ $[0.001, 0.01]$	$/byte $/s
	Cost for computation	π^{FG} π_{idle}^{FG}	$[5*10^{-16}, 5*10^{-15}]$ $[5*10^{-7}, 5*10^{-6}]$	$/byte $/s
	Cost for storage	ω^{FG} ω_{idle}^{FG}	$[10^{-16}, 10^{-15}]$ $[10^{-8}, 10^{-7}]$	$/byte $/s
Cloud	Power consumption for data forwarding	α^{CL} α_{idle}^{CL}	$[5*10^{-7}, 5*10^{-5}]$ $[50, 200]$	W/byte W
	Power consumption for computation	β^{CL} β_{idle}^{CL}	$[10^{-9}, 10^{-7}]$ $[100, 200]$	W/byte W
	Power consumption for storage	γ^{CL} γ_{idle}^{CL}	$[5*10^{-9}, 5*10^{-7}]$ $[50, 100]$	W/byte W
	Delay of transmission	δ_{fc}^{CL}	$[10^{-6}, 10^{-5}]$	s/byte
	Delay of processing	λ^{CL}	$[10^{-9}, 10^{-8}]$	
	Cost for data forwarding	σ^{CL} σ_{idle}^{CL}	$[5*10^{-10}, 5*10^{-9}]$ $[0.001, 0.01]$	$/byte $/s
	Cost for computation	π^{CL} π_{idle}^{CL}	$[5*10^{-15}, 5*10^{-14}]$ $[5*10^{-7}, 5*10^{-6}]$	$/byte $/s
	Cost for storage	ω^{CL} ω_{idle}^{CL}	$5*10^{-16}, 5*10^{-16}]$ $[10^{-8}, 10^{-7}]$	$/byte $/s

Table 2: The Coefficient of Variation results of different models after 10 trials for different test case and different performance metrics

Task	Model	ER	GD	IGD	STE	HV	HAR
50	NSGA-II	0.405	0.218	**0.053**	2.458	0.021	0.021
	NSGA-III	0.168	**0.196**	0.075	**0.830**	0.019	0.019
	MO-ALO	**0.377**	0.367	0.079	0.839	**0.014**	**0.014**
	MO-SSA	0.421	0.330	0.652	2.688	0.021	0.021
100	NSGA-II	0.238	**0.107**	**0.048**	0.834	**0.017**	**0.017**
	NSGA-III	0.337	0.219	0.049	0.858	0.019	0.019
	MO-ALO	0.406	0.309	0.050	**0.557**	0.020	0.020
	MO-SSA	**0.212**	0.458	0.342	0.752	0.026	0.026
150	NSGA-II	0.313	0.340	**0.036**	**0.561**	**0.014**	**0.014**
	NSGA-III	0.350	**0.321**	0.042	1.921	**0.014**	**0.014**
	MO-ALO	0.309	0.465	0.052	0.935	0.015	0.015
	MO-SSA	**0.206**	0.352	0.175	0.576	0.018	0.018
200	NSGA-II	0.307	0.178	0.037	0.665	0.015	0.015
	NSGA-III	0.241	**0.158**	**0.033**	0.506	0.021	0.021
	MO-ALO	0.344	0.239	0.035	0.818	**0.012**	**0.012**
	MO-SSA	**0.123**	0.184	0.195	**0.474**	0.015	0.015
250	NSGA-II	0.287	0.273	0.043	1.346	**0.009**	**0.009**
	NSGA-III	0.343	0.270	0.053	1.195	0.017	0.017
	MO-ALO	0.326	0.329	**0.034**	0.820	0.010	0.010
	MO-SSA	**0.162**	**0.153**	0.157	**0.573**	0.011	0.011
300	NSGA-II	0.237	0.262	0.043	0.702	**0.011**	**0.011**
	NSGA-III	0.319	0.272	**0.025**	1.302	0.020	0.020
	MO-ALO	0.311	0.345	0.033	0.998	0.017	0.017
	MO-SSA	**0.065**	**0.212**	0.189	**0.368**	**0.011**	**0.011**
350	NSGA-II	0.236	0.140	0.031	1.027	**0.014**	**0.014**
	NSGA-III	0.258	**0.112**	**0.040**	0.798	**0.014**	**0.014**
	MO-ALO	0.469	0.468	0.045	1.175	0.020	0.020
	MO-SSA	**0.136**	0.291	0.177	**0.720**	0.024	0.024
400	NSGA-II	0.343	**0.137**	**0.023**	1.250	0.017	0.017
	NSGA-III	0.298	0.173	0.027	0.858	**0.010**	**0.010**
	MO-ALO	0.474	0.429	0.045	1.220	0.021	0.021
	MO-SSA	**0.120**	0.270	0.136	**0.291**	0.014	0.014
450	NSGA-II	0.322	**0.113**	**0.028**	2.392	0.014	0.014
	NSGA-III	0.322	0.318	0.041	1.283	**0.013**	**0.013**
	MO-ALO	0.363	0.542	0.046	0.423	0.016	0.016
	MO-SSA	**0.139**	0.251	0.203	**0.229**	0.026	0.026
500	NSGA-II	0.285	0.209	0.032	1.109	0.011	0.011
	NSGA-III	0.324	**0.197**	**0.027**	1.633	0.011	0.011
	MO-ALO	0.365	0.355	0.042	0.623	0.010	0.126
	MO-SSA	**0.030**	0.335	0.114	**0.407**	**0.009**	**0.009**

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