Table 4. BPO in Data Layer (Block Expansion and Parameters Adjustment)

Ref.	Optimization Objects [Main Baselines]	Scenarios	Experiment [Applicable] Platforms	Parameters	Impact on Decentralization [Security]
[56]	• Latency	—	Simulation [PoW-Based]	• Block Size	Yes [Yes]
[57]	• Latency	—	HLF [HLF]	• Block Size • Block Packing Interval • Number of Nodes and Other Parameters in HLF	Yes [Yes]
[58]	• Latency [HLF]	• IoV	HLF [HLF]	• Block Size and Other 2 Parameters in HLF	Yes [Yes]
BPR [59]	• Throughput • Latency [HLF]†	• ITS	HLF [Permissioned]	• Block Size	Yes [Yes]
Learning-Chain [60]	• Throughput • Latency [HLF]†	• ITS	HLF [Permissioned]	• Block Size • Block Packing Interval • Number of Nodes	Yes [Yes]
[61]	• Throughput	• IoT	Simulation [Permissioned]	• Block Size • Block Packing Interval • Number of Shards	No [Yes]
[62]	• Throughput • Latency	• IoT	Simulation [Permissioned]	• Block Size • Block Packing Interval • Consensus Mechanism	Yes [Yes]
PerBlocks [63]	• Throughput • Latency	• IoT	Simulation [Permissioned]	• Block Size • Consensus Mechanism	Yes [Yes]
RLChain [64]	• Throughput • Latency	• IIoT	Simulation [Permissionless]	• Block Size • Block Packing Interval	Yes [Yes]
[65]	• Throughput • Latency [HLF]†	• EHR	HLF [HLF]	• Transaction Arrival Rate	Yes [Yes]

(Continued.)

Table 4. *(Continued.)* BPO in Data Layer (DAG-Based Blockchain Structure Optimization)

Ref.	Optimization Objects [Main Baselines]	Scenarios	Experiment [Applicable Platforms]	Impact on Decentralization [Security]
CoDAG [66]	• Throughput [Bitcoin, Ethereum]	—	Prototype [Limitless]	No [Yes]
GpDB [67]	• Throughput [IOTA]	• IIoT	Simulation [Limitless]	No [Yes]
MorphDAG [68]	• Throughput • Latency	—	Prototype [Permissionless]	Yes [Yes]
Nezha [70]	• Throughput • Latency	—	Prototype [Permissionless]	No [Yes]
AdaptChain [69]	• Throughput	—	Prototype [Permissionless]	No [Yes]
FLUID [71]	• Throughput • Latency	—	Prototype [Permissionless]	No [Yes]
OptME [72]	• Throughput	—	Prototype [Permissionless]	No [Yes]

Received 20 February 2025

Table 5. BPO in Network Layer (Sharding)

Ref.	Optimization Objects [Main Baselines]	Scenarios	Experiment [Applicable] Platforms	State Models [Consensus Mechanisms]	Impact on Decentralization [Security]
[77]	• Throughput • Latency • CC	• 6G	FISCO BCOS [Permissioned]	• Account [PBFT]	Yes [Yes]
SharPer [78]	• Throughput • Latency • CO	—	Prototype [Permissioned]	• Account [PBFT/ Raft]	Yes [Yes]
MaOEA-DRP [79]	• Throughput • Latency	• IIoT	Simulation [Permissioned]	— [PBFT]	Yes [Yes]
MaOEA-IE [80]	• Throughput • Latency • CC	• EC • IoT	Simulation [Permissioned]	— [PBFT]	Yes [Yes]
MSLShard [81]	• Throughput • Latency [RapidChain]†	• IoT	Prototype [Permissioned]	• Account [—]	Yes [Yes]
[82]	• Throughput • Latency [Monoxide]†	—	Simulation [Permissioned]	• Account [PBFT]	Yes [Yes]
[83]	• Throughput	• IoT	Simulation [Permissioned]	— [PBFT]	Yes [Yes]
[84]	• Throughput • Latency • CO • CC [Pyramid]†	• WN	Simulation [Permissioned]	— [PBFT]	Yes [Yes]
CoChain [85]	• Throughput • Latency [Harmony [231]]†	—	Prototype [Permissionless]	• Account [PBFT]	Yes [Yes]
SmartChain [86]	• Throughput	• IoT	Simulation [Permissioned]	• Account [PBFT]	Yes [Yes]
[87]	• Throughput • Latency	—	Simulation [Permissioned]	• UTXO [PBFT]	Yes [Yes]
[88]	• Throughput	—	Simulation [Permissioned]	• UTXO [PBFT]	No [Yes]
ATCF [90]	• Throughput	• 5G • IoT	Simulation [Permissioned]	— [—]	Yes [Yes]
[93]	• Throughput • Latency [Monoxide]†	—	Simulation [Account-Based]	• Account [PBFT]	No [Yes]
BrokerChain [92]	• Throughput • Latency [Monixide]†	—	Prototype [Permissionless]	• Account [PBFT]	No [Yes]
EfShard [94]	• Throughput • Latency • CO	—	Prototype [Permissioned]	• Account [BFT-Based]	No [Yes]
[95]	• Throughput • Latency	—	HLF [Permissioned]	• Account [Fast BFT[232]]	Yes [Yes]
HMMDShard [96]	• Throughput • Latency [Omniledger]†	• IoT	Prototype [Permissioned]	• Account [PBFT]	Yes [Yes]
Estuary [97]	• Throughput • Latency [Omniledger]†	—	Prototype [Permissioned]	• UTXO [PBFT]	Yes [Yes]
TxAllo [98]	• Throughput • Latency	—	Simulation [Permissionless]	• Account [BFT-Based]	Yes [Yes]
X-Shard [99]	• Throughput • Latency • CO	—	Prototype [Permissioned]	• Account [PBFT]	Yes [Yes]
Sliver [100]	• Throughput [Pyramid]	—	Simulation [Limitless]	• Account [—]	Yes [Yes]
SharDAG [101]	• Throughput • Latency [Monoxide]	—	Prototype [Limitless]	• Account [BFT-Based]	Yes [Yes]

(Continued.)

Table 5. *(Continued.)* BPO in Network Layer (Sharding)

Ref.	Optimization Objects [Main Baselines]	Scenarios	Experiment [Applicable] Platforms	State Models [Consensus Mechanisms]	Impact on Decentralization [Security]
Pyramid [102]	• Throughput • Latency [Monoxide]†	—	Prototype [Permissionless]	• Account • UTXO [Proposed]	Yes [Yes]
LSMD [103]	• Throughput • Latency	• CDT	Prototype [Permissionless]	• Account [—]	Yes [Yes]
OverShard [104]	• Throughput	—	Prototype [Permissionless]	• Account [PoW]	Yes [Yes]
DRL-OSS [105]	• Throughput [Omniledger]	• IIoT	Simulation [Permissioned]	• Account [PBFT]	Yes [Yes]
FS [106]	• Throughput • Latency • CO [Omniledger]†	—	Simulation [Permissioned]	• UTXO [Proposed]	Yes [Yes]
OSOM [107]	• Throughput • Latency [Pyramid]†	• IIoT	Simulation [Permissionless]	• Account [PoS]	Yes [Yes]
Reticulum [108]	• Throughput	—	Prototype [Permissionless]	— [Proposed]	Yes [Yes]
Benzene [109]	• Throughput • Latency [Monoxide]†	—	Prototype [Permissioned]	• Account [Proposed]	No [Yes]
Prophet [110]	• Throughput • Latency [Monoxide]†	—	Prototype [Permissionless]	• Account [Proposed]	No [Yes]
[112]	• Throughput • CO	—	Ethereum [Permissionless]	• Account [PoW]	Yes [Yes]
Jenga [113]	• Throughput • Latency [Pyramid]†	—	Prototype [Permissionless]	• Account [Proposed]	No [Yes]
Meepo [114]	• Throughput • Latency	—	Prototype [Permissioned]	• Account [PBFT]	No [Yes]

(Continued.)

Table 5. *(Continued.)* BPO in Network Layer (Data Transmission and Propagation)

Ref.	Optimization Objects [Main Baselines]	Scenarios	Experiment [Applicable] Platforms	Optimization Propagation Processes	Impact on Decentralization [Security]
[116]	• Throughput	• IoT • WN	Simulation [Limitless]	• Transaction • Block	Yes [Yes]
BlockP2P-EP [117]	• Latency • CO [Bitcoin, Ethereum]†	—	Prototype [Permissionless]	• Transaction • Block	Yes [Yes]
Swift [118]	• Throughput • Latency • CO [Flooding]†	—	Prototype [Permissionless]	• Transaction • Block	Yes [Yes]
TBGN [119]	• Latency • CO [Gossip]†	• IoT	Simulation [Permissioned]	• Transaction • Block	Yes [Yes]
CDTS [120]	• Latency • CO [BlockP2P-EP]†	• IIoT	Simulation [Permissioned]	• Transaction • Block	Yes [Yes]
Shrec [123]	• Throughput • Latency • CO • CC	—	Conflux [Permissionless]	• Transaction	No [Yes]
Mercury [124]	• Latency [BlockP2P]	—	Conflux [Permissionless]	• Transaction	No [Yes]
CSTNs [125]	• Latency • Throughput	• IoT	Simulation [Limitless]	• Transaction • Block	Yes [Yes]

(Continued.)

Table 5. *(Continued.)* BPO in Network Layer (Data Verification)

Ref.	Optimization Objects [Main Baselines]	Scenarios	Experiment [Applicable] Platforms	Optimization Verification Processes	Impact on Decentralization [Security]
EBV [89]	• Latency [Bitcoin]	—	Bitcoin [Permissionless]	• Block	No [No]
[126]	• Throughput • Latency	• IoT	HLS [Permissioned]	• Block	No [Yes]
POBL [126]	• Throughput • Latency	—	HLF [Permissioned]	• Transaction • Block	No [Yes]
CTV [128]	• Throughput • Latency	—	Bitcoin [Permissionless]	• Transaction	No [Yes]

Table 6. BPO in Consensus Layer

Domain	Ref.	Optimization Objects [Main Baselines]	Scenarios	Experiment [Applicable] Platforms	Fault Tolerance	Impact on Decentralization [Security]
Proof -Based	EPoW [129]	• Throughput • Latency [DPoS] • CO	• IoV	md_blockchain[233] [Permissioned]	50% CP	Yes [Yes]
	Relay-PoW [130]	• Throughput • Latency • CC [PoW]†	• IoT	Simulation [Permissionless]	50% CP	Yes [Yes]
	Green-PoW [131]	• CC [PoW]	—	Simulation [Permissionless]	50% CP	Yes [Yes]
	EPoW [132]	• CC [PoW]	—	Simulation [Permissionless]	50% CP	No [Yes]
	SMP [133]	• Throughput • CO • CC [PoW]†	• IoT	Simulation [Permissionless]	50% CP	Yes [Yes]
	TBTC-PoW [134]	• CC [PoW]	• IoT	Simulation [Permissionless]	50% CP	Yes [Yes]
	PoTW [135]	• Throughput • Latency [PoW]†	• EC	Simulation [Permissionless]	50% CP	Yes [Yes]
	Dispatcher [136]	• Throughput [OHIE]	—	Prototype [Permissionless]	50% CP	Yes [Yes]
	PoM [137]	• Throughput • Latency • CC [PoW]†	• SSLA	Prototype [Permissionless]	50% BN	No [Yes]
	[138]	• Throughput • Latency [PBFT]†	—	Simulation [Limitless]	⊙	No [Yes]
	PoN [139]	• Latency • CO [PoR]†	—	Simulation [Permissionless]	50% BN	No [Yes]
	QV-DPoS [140]	• CC [PoW, PoA]	• IoT	Simulation [Permissionless]	33% BN	Yes [Yes]
	PoMC [141]	• Throughput [PBFT] • Latency • CO [PBFT]	• IoT	Simulation [Permissioned]	33% BN	No [Yes]
	OHIE [142]	• Throughput • Latency	—	Prototype [Permissionless]	50% CP	No [Yes]
	VaaP [143]	• Throughput • Latency [Sphinx]†	—	Prototype [Permissioned]	33% BN	Yes [Yes]
	RainBlock [144]	• Throughput [Ethereum]	—	Prototype [Permissionless]	50% CP	No [No]

(Continued.)

Table 6. *(Continued.)* BPO in Consensus Layer

Domain	Ref.	Optimization Objects [Main Baselines]	Scenarios	Experiment [Applicable] Platforms	Fault Tolerance	Impact on Decentralization [Security]
BFT -Based	EB-BFT [146]	• Throughput • Latency	—	Simulation [Permissioned]	33% BN	Yes [Yes]
	TSBFT [147]	• Throughput • Latency • CO	—	Simulation [Permissioned]	33% BN	Yes [Yes]
	TRUG-PBFT [148]	• Throughput • Latency • CO text[PBFT]†	• IoV	Simulation [Permissioned]	33% BN	Yes [Yes]
	[149]	• Throughput • Latency • CO • CC [DPoS, PBFT]†	—	Prototype [Permissioned]	40% BN	Yes [Yes]
	GroupedPBFT [150]	• Latency [PBFT]	• Flight	Ethereum [Permissioned]	33% BN	Yes [Yes]
	RRV-BC [151]	• Throughput • CO [PBFT]†	• IoT	Simulation [Limitless]	33% BN	Yes [Yes]
	LS-PBFT [152]	• Latency • CO [PBFT]†	• IoV	Prototype [Permissioned]	33% BN	Yes [Yes]
	[153]	• Latency [PBFT]	• EHR	Simulation [Permissioned]	33% BN	Yes [Yes]
	SCBC [154]	• Throughput • Latency • CO [PBFT]†	• WN	Simulation [Permissioned]	33% BN	Yes [Yes]
	mPBFT [155]	• Latency • CO • CC	• IoV • SDN	Simulation [Permissioned]	33% BN	No [Yes]
	Gosig [156]	• Throughout [HLF] • Latency • CO	—	Prototype [Permissioned]	33% BN	No [Yes]
	LRBP [157]	• Throughput • Latency [PBFT]†	• WN	Simulation [Limitless]	50% BN	No [Yes]
	[158]	• Latency • CO [PBFT]	• Smart City	Simulation [Permissionless]	33% BN	Yes [Yes]
	RARC [159]	• Throughput • Latency • CO [PBFT]†	• IoT	Simulation [Permissioned]	33% BN	Yes [Yes]
	ME-BFT [160]	• Throughput • Latency • CO	• EHR	Simulation [Permissioned]	33% BN	Yes [Yes]
	HiCoOB [161]	• Throughput • Latency • CO	• Energy	Prototype [Permissioned]	33% BN	Yes [Yes]
	TP-PBFT [162]	• Latency • CO [PBFT]†	• IoT	Simulation [Permissioned]	33% BN	Yes [Yes]
	HierBFT [163]	• Throughput • Latency • CO [PBFT]†	• IoV	Prototype [Permissioned]	33% BN	Yes [Yes]
	DPBFT [164]	• Throughput • Latency [PBFT]†	• IoT • 5G	Prototype [Permissioned]	⊕	Yes [Yes]

(Continued.)

Table 6. *(Continued.)* BPO in Consensus Layer

Domain	Ref.	Optimization Objects [Main Baselines]	Scenarios	Experiment [Applicable] Platforms	Fault Tolerance	Impact on Decentralization [Security]
BFT -Based	MuLCOff [165]	• Throughput • Latency • CC [PBFT]†	• Energy	Prototype [Permissioned]	33% BN	Yes [Yes]
	[166]	• Throughput • Latency	—	Prototype [Permissioned]	33% BN	Yes [Yes]
	Anony-mousFox [167]	• Throughput • Latency • CO • CC	—	Ethereum [Permissioned]	33% BN	Yes [No]
	SG-PBFT [168]	• Throughput • Latency • CO	• IoV	Simulation [Permissioned]	33% BN	Yes [Yes]
	SVBFT [169]	• Throughput • Latency • CO [PBFT]†	• IoT	HLF [Permissioned]	33% BN	Yes [Yes]
	Proteus [170]	• Throughput • Latency • CO [PBFT]†	—	Prototype [Permissioned]	33% BN	Yes [No]
	BAASH [171]	• Throughput [HLF, Ethereum] • Latency • CC	HPC	Prototype [Permissioned]	33% BN	No [Yes]
	[172]	• Throughput • Latency [PBFT, HotStuff]†	—	Prototype [Permissioned]	33% BN	No [Yes]
	[173]	• Throughput • Latency [PBFT]†	—	Simulation [Permissioned]	33% BN	No [Yes]
	[174]	• Throughput • Latency • CO [PBFT]†	• IoT	Prototype [Permissioned]	33% BN	No [Yes]
	AAPP [175]	• Throughput • CO [PBFT]†	EC	Simulation [Permissioned]	33% BN	Yes [Yes]
	DR-BFT [176]	• Throughput • Latency • CO [PBFT]†	• EC	Simulation [Permissioned]	33% BN	No [Yes]
	ABFT [178]	• Throughput • Latency • CC [HoneyBadger]†	• IoT	Prototype [Permissioned]	33% BN	No [Yes]
	[179]	• Latency [PBFT, Raft, DPoS]	• Energy	Prototype [Permissioned]	50% BN	Yes [Yes]
	MPH [181]	• Throughput [HotStuff]	—	Prototype [Permissioned]	33% BN	No [No]
	Efficient-HotStuff [182]	• Throughput • Latency [HotStuff]†	—	Prototype [Permissioned]	33% BN	No [Yes]
	Dolphin [183]	• Throughput • Latency [PBFT]†	—	Prototype [Permissioned]	33% BN	No [No]
	[184]	• Throughput • Latency [HotStuff]†	• IoV	Simulation [Permissioned]	33% BN	No [Yes]

(Continued.)

Table 6. *(Continued.)* BPO in Consensus Layer

Domain	Ref.	Optimization Objects [Main Baselines]	Scenarios	Experiment [Applicable] Platforms	Fault Tolerance	Impact on Decentralization [Security]
BFT -Based	Teegraph [187]	• Throughput • Latency [Hashgraph]†	• IoT	Simulation [Limitless]	50% BN	Yes [Yes]
	Jointgraph [188]	• Throughput • Latency [Hashgraph]†	—	Simulation [Permissioned]	33% BN	Yes [Yes]
	DAG-D [189]	• Throughput • Latency • CO [CoDAG]†	• IIoT	Prototype [Limitless]	33% BN	Yes [Yes]
	GradedDAG [192]	• Throughput • Latency	—	Prototype [Limitless]	33% BN	No [Yes]
	Wahoo [193]	• Throughput • Latency [GradedDAG]†	—	Prototype [Limitless]	33% BN	No [Yes]
	[194]	• Throughput • Latency [Ethereum]†	—	Sphinx [Permissioned]	33% BN	Yes [Yes]
	NimbleChain [194]	• Latency [Ethereum]	—	Prototype [Permissionless]	50% CP	No [Yes]
	[196]	• Throughput • Latency	—	Fisco BCOS [Permissioned]	—	Yes [Yes]
CFT -Based	Raft+ [198]	• Latency	• IoT	Similation [Permissioned]	50% CN	Yes [Yes]
	KRaft [199]	• Throughput • CO [Raft]†	—	Simulation [Permissioned]	50% CN	No [Yes]
	VSSB-Raft [201]	• Throughput • Latency [Raft]†	—	Prototype [Permissioned]	50% CN	No [Yes]
	R-Raft [202]	• Latency • CC [Raft]†	• MEC	Simulation [Permissioned]	50% CN	No [Yes]
Hybrid	RBCP [203]	• Throughput • Latency • CO [PoW, PoS, PoA]†	• IoT	Simulation [Limitless]	50% CP	Yes [Yes]
	PoQ [204]	• Throughput	—	Simulation [Perimissionless]	33% BN	Yes [Yes]
	[205]	• Throughput • Latency • CC [PBFT, Raft]†	• Metaverse	Prototype [Perimissioned]	—	Yes [Yes]
	PPoR [206]	• Throughput • Latency [PoW, PBFT]†	• IoV	Simulation [Permissioned]	20% BN	Yes [Yes]
	VDC [207]	• Latency [PBFT]	—	Simulation [Permissioned]	50% BN	Yes [Yes]
	WRBFT [208]	• Throughput • Latency • CO [PBFT]†	• IoV	Simulation [Permissioned]	⊙	Yes [Yes]

(Continued.)

BN: Byzantine Nodes; CN: Crash Nodes; CP: Computing Power.
†: All optimization objects used these baselines.
⊕: Depends on the number of groups and the number of nodes in the group. ⊙: Adaptive adjustment to network conditions