Appendix A. Search Queries

- ***Google Scholar, IEEE Digital Library and Science Direct:*** *(Blockchain OR bitcoin OR ethereum OR cryptocurrencies OR cryptocurrency OR "digital currency" OR "distributed ledger" OR "DLT" OR "Merkel tree" OR "smart contract platform" OR "tokenized asset") AND (Centralization OR centralisation OR Centralism OR consolidation OR decentralisation OR decentralization OR devolution OR Dominating OR Domination OR Monopolisation OR Monopolization OR monopoly OR oligopoly OR singular OR unipolar)*

- ***ACM Digital Library:*** *+(Blockchain bitcoin ethereum blockchains cryptocurrencies cryptocurrency "digital currency" "distributed ledger" DLT "Merkel tree" "smart contract platform" "tokenized asset") +(Centralization centralisation Centralism concentration consolidation Control decentralisation decentralization devolution Dominating Domination managed Monopolisation Monopolization monopoly oligopoly singular unipolar)*

- ***ISI Web of Science:*** *(TS=((Blockchain OR bitcoin OR ethereum OR cryptocurrencies OR cryptocurrency OR "digital currency" OR "distributed ledger" OR DLT OR "merkel tree" OR "smart contract platform" OR "tokenized asset") AND (Centralization OR centralisation OR Centralism OR consolidation OR decentralisation OR decentralization OR devolution OR Dominating OR Domination OR managed OR Monopolisation OR Monopolization OR monopoly OR oligopoly OR singular OR unipolar))) AND LANGUAGE: (English)*

- ***Scopus:*** *((TITLE-ABS-KEY (blockchain OR bitcoin OR ethereum OR cryptocurrencies OR cryptocurrency OR "digital currency" OR "distributed ledger" OR dlt OR "merkel tree" OR "smart contract platform" OR "tokenized asset") AND (centralization OR centralisation OR centralism OR consolidation OR decentralisation OR decentralization OR devolution OR dominating OR domination OR managed OR monopolisation*

OR monopolization OR monopoly OR oligopoly OR singular OR unipolar)) AND PUBYEAR ¿ 2008 AND (LIMIT-TO (LANGUAGE , "English"))

- ***Springer Link:*** *(blockchain — bitcoin — ethereum — cryptocurrencies — cryptocurrency — "digital currency" — "distributed ledger" — "merkel tree" — "smart contract platform" — "tokenized asset") & (centralization — centralisation — Centralism — consolidation — decentralisation — decentralization — devolution — Dominating — Domination — Monopolisation — Monopolization — monopoly — oligopoly — singular — unipolar)*

Appendix B. Selected Articles

References

[R1] F. Zhu, W. Chen, Y. Wang, P. Lin, T. Li, X. Cao, L. Yuan, Trust your wallet: A new online wallet architecture for bitcoin, in: 2017 International Conference on Progress in Informatics and Computing (PIC), IEEE, 2017, pp. 307–311.

[R2] L. J. Valdivia, C. Del-Valle-Soto, J. Rodriguez, M. Alcaraz, Decentralization: The failed promise of cryptocurrencies, IT Professional 21 (2) (2019) 33–40.

[R3] G. Vidan, V. Lehdonvirta, Mine the gap: Bitcoin and the maintenance of trustlessness, New Media & Society 21 (1) (2019) 42–59.

[R4] Y. Zhang, The incompatibility of bitcoin's strong decentralization ideology and its growth as a scalable currency, NYUJL & Liberty 11 (2017) 556.

[R5] D. Zambre, A. Shah, Analysis of bitcoin network dataset for fraud, Unpublished Report 27.

Table B.11: List of Selected Articles

Centralization Factor	Selected Articles
Wallet Concentration	[R1, R2, R3, R4, R5, R6, R7, R8, R9]
Exchange Concentration	[R3, R4, R10, R11, R12, R13, R14, R5, R15, R7, R8, R16, R9]
Reference Client Concentration	[R17, R18, R19, R20, R21, R22, R6, R23]
Storage Growth Rate	[R24, R25, R26, R27, R28, R29]
Specialized Equipment Concentration	[R30, R31, R32, R33, R21, R34, R35]
Wealth Concentration	[R32, R33, R21, R34, R35, R36]
Consensus Power Distribution	[R37, R6, R38, R31, R39, R32, R40, R25, R41, R42, R43, R44, R2, R45, R46, R47, R48, R3, R49, R50, R51, R52, R53, R54, R55, R36, R56, R57, R58, R59, R60, R61, R62, R33, R63, R21, R64, R65, R66, R67, R68, R69, R70, R71, R27, R72, R73, R74, R75, R76, R77, R7, R78, R23, R79, R8, R80, R81, R9, R82, R83]
Node Discovery Protocol Control	[R84]
Geographic Distribution	[R44, R2, R50, R18, R76, R57, R8]
Bandwidth Concentration	[R43, R76]
Routing Centralization	[R58, R80, R76]
Owner Control	[R23, R85, R86, R42, R87]
Improvement Protocol	[R23, R85, R2, R17, R88, R19, R57, R22, R6, R87, R89]

[R6] A. Gervais, G. O. Karame, V. Capkun, S. Capkun, Is bitcoin a decentralized currency?, IEEE security & privacy 12 (3) (2014) 54–60.

[R7] R. Böhme, N. Christin, B. Edelman, T. Moore, Bitcoin: Economics, technology, and governance, Journal of economic Perspectives 29 (2) (2015) 213–38.

[R8] G. Hileman, M. Rauchs, Global cryptocurrency benchmarking study, Cambridge Centre for Alternative Finance 33.

[R9] A. Beikverdi, J. Song, Trend of centralization in bitcoin's distributed network, in: 2015 IEEE/ACIS 16th International Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing (SNPD), IEEE, 2015, pp. 1–6.

[R10] T. Moore, N. Christin, Beware the middleman: Empirical analysis of bitcoin-exchange risk, in: International Conference on Financial Cryptography and Data Security, Springer, 2013, pp. 25–33.

[R11] P. Giudici, G. Polinesi, Crypto price discovery through correlation networks, Annals of Operations Research (2019) 1–15.

[R12] N. Gandal, J. Hamrick, T. Moore, T. Oberman, Price manipulation in the bitcoin ecosystem, Journal of Monetary Economics 95 (2018) 86–96.

[R13] S. Ranshous, C. A. Joslyn, S. Kreyling, K. Nowak, N. F. Samatova, C. L. West, S. Winters, Exchange pattern mining in the bitcoin transaction directed hypergraph, in: International Conference on Financial Cryptography and Data Security, Springer, 2017, pp. 248–263.

[R14] M. Zima, Coincer: Decentralised trustless platform for exchanging decentralised cryptocurrencies, in: International Conference on Network and System Security, Springer, 2017, pp. 672–682.

[R15] C. Decker, R. Wattenhofer, Bitcoin transaction malleability and mtgox, in: European Symposium on Research in Computer Security, Springer, 2014, pp. 313–326.

[R16] P. Tasca, A. Hayes, S. Liu, The evolution of the bitcoin economy, The Journal of Risk Finance.

[R17] S. Azouvi, M. Maller, S. Meiklejohn, Egalitarian society or benevolent dictatorship: The state of cryptocurrency governance, in: International Conference on Financial Cryptography and Data Security, Springer, 2018, pp. 127–143.

[R18] S. K. Kim, Z. Ma, S. Murali, J. Mason, A. Miller, M. Bailey, Measuring ethereum network peers, in: Proceedings of the Internet Measurement Conference 2018, 2018, pp. 91–104.

[R19] M. Zachariadis, G. Hileman, S. V. Scott, Governance and control in distributed ledgers: understanding the challenges facing blockchain technology in financial services, Information and Organization 29 (2) (2019) 105–117.

[R20] A. I. Badev, M. Chen, Bitcoin: Technical background and data analysis, Finance and Economics Discussion Series.

[R21] N. Roubini, The big blockchain lie, Project Syndicate. Blog post. Oct 15.

[R22] F. Armknecht, G. O. Karame, A. Mandal, F. Youssef, E. Zenner, Ripple: Overview and outlook, in: International Conference on Trust and Trustworthy Computing, Springer, 2015, pp. 163–180.

[R23] P. De Filippi, B. Loveluck, The invisible politics of bitcoin: governance crisis of a decentralized infrastructure, Internet Policy Review 5 (4).

[R24] M. Dai, S. Zhang, H. Wang, S. Jin, A low storage room requirement framework for distributed ledger in blockchain, IEEE Access 6 (2018) 22970–22975.

[R25] R. Han, N. Foutris, C. Kotselidis, Demystifying crypto-mining: Analysis and optimizations of memory-hard pow algorithms, in: 2019 IEEE International Symposium on Performance Analysis of Systems and Software (ISPASS), IEEE, 2019, pp. 22–33.

[R26] Y. Xu, Section-blockchain: A storage reduced blockchain protocol, the foundation of an autotrophic decentralized storage architecture, in: 2018 23rd International Conference on Engineering of Complex Computer Systems (ICECCS), IEEE, 2018, pp. 115–125.

[R27] S. Bano, M. Al-Bassam, G. Danezis, The road to scalable blockchain designs, USENIX; login: magazine.

[R28] Z. Guo, Z. Gao, H. Mei, M. Zhao, J. Yang, Design and optimization for storage mechanism of the public blockchain based on redundant residual number system, IEEE Access 7 (2019) 98546–98554.

[R29] D. Perard, J. Lacan, Y. Bachy, J. Detchart, Erasure code-based low storage blockchain node, in: 2018 IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData), IEEE, 2018, pp. 1622–1627.

[R30] Cryptoslate, Ethereum network under assault: Gas price manipulation may indicate covert eos attack [interview] (Sep 2018).
URL https://cryptoslate.com/ethereum-network-under-assault-gas-price\-manipulation-may-indicate-covert-eos-attack

[R31] K. Liao, J. Katz, Incentivizing blockchain forks via whale transactions, in: International Conference on Financial Cryptography and Data Security, Springer, 2017, pp. 264–279.

[R32] Z. Liu, S. Tang, S. S. Chow, Z. Liu, Y. Long, Fork-free hybrid consensus with flexible proof-of-activity, Future Generation Computer Systems 96 (2019) 515–524.

[R33] J. A. Kroll, I. C. Davey, E. W. Felten, The economics of bitcoin mining, or bitcoin in the presence of adversaries, in: Proceedings of WEIS, Vol. 2013, 2013, p. 11.

[R34] G. Paul, P. Sarkar, S. Mukherjee, Towards a more democratic mining in bitcoins, in: International Conference on Information Systems Security, Springer, 2014, pp. 185–203.

[R35] D. Kondor, M. Pósfai, I. Csabai, G. Vattay, Do the rich get richer? an empirical analysis of the bitcoin transaction network, PloS one 9 (2).

[R36] F. Caccioli, G. Livan, T. Aste, Scalability and egalitarianism in peer-to-peer networks, in: Banking beyond banks and money, Springer, 2016, pp. 197–212.

[R37] L. W. Cong, Z. He, J. Li, Decentralized mining in centralized pools, Tech. rep., National Bureau of Economic Research (2019).

[R38] A. R. Sai, J. Buckley, A. Le Gear, Assessing the security implication of bitcoin exchange rates, Computers and Security.

[R39] N. Shi, A new proof-of-work mechanism for bitcoin, Financial Innovation 2 (1) (2016) 31.

[R40] F. Bruschi, V. Rana, L. Gentile, D. Sciuto, Mine with it or sell it: the superhashing power dilemma, ACM SIGMETRICS Performance Evaluation Review 46 (3) (2019) 127–130.

[R41] R. Nakahara, H. Inaba, Proposal of fair proof-of-work system based on rating of user's computing power, in: 2018 IEEE 7th Global Conference on Consumer Electronics (GCCE), IEEE, 2018, pp. 746–748.

[R42] X. Boyen, C. Carr, T. Haines, Graphchain: A blockchain-free scalable decentralised ledger, in: Proceedings of the 2nd ACM Workshop on Blockchains, Cryptocurrencies, and Contracts, 2018, pp. 21–33.

[R43] Z. Zheng, S. Xie, H.-N. Dai, X. Chen, H. Wang, Blockchain challenges and opportunities: A survey, International Journal of Web and Grid Services 14 (4) (2018) 352–375.

[R44] A. Ekblaw, C. Barabas, J. Harvey-Buschel, A. Lippman, Bitcoin and the myth of decentralization: Socio-technical proposals for restoring network integrity, in: 2016 IEEE 1st International Workshops on Foundations and Applications of Self* Systems (FAS* W), IEEE, 2016, pp. 18–23.

[R45] J.-B. Kim, H. Park, A study on the comparative analysis of bitcoin miner, International Journal of Innovative Technology and Exploring Engineering 8 (4S2) (2019) 459–463.

[R46] C. T. Nguyen, D. T. Hoang, D. N. Nguyen, D. Niyato, H. T. Nguyen, E. Dutkiewicz, Proof-of-stake consensus mechanisms for future blockchain networks: fundamentals, applications and opportunities, IEEE Access 7 (2019) 85727–85745.

[R47] N. Alzahrani, N. Bulusu, Towards true decentralization: A blockchain consensus protocol based on game theory and randomness, in: International Conference on Decision and Game Theory for Security, Springer, 2018, pp. 465–485.

[R48] C. Carr, C. Boyd, X. Boyen, T. Haines, Bitcoin unchained, Blockchain Engineering (2017) 15.

[R49] L. Crane, Bitcoin currency dominated by a few big players, New scientist (2018) 10.

[R50] I. E. Khairuddin, C. Sas, An exploration of bitcoin mining practices: Miners' trust challenges and motivations, in: Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems, 2019, pp. 1–13.

[R51] I. Tsabary, I. Eyal, The gap game, in: Proceedings of the 2018 ACM SIGSAC conference on Computer and Communications Security, 2018, pp. 713–728.

[R52] Y. Kano, T. Nakajima, A novel approach to solve a mining work centralization problem in blockchain technologies, International Journal of Pervasive Computing and Communications.

[R53] D. Azzolini, F. Riguzzi, E. Lamma, E. Bellodi, R. Zese, et al., Modeling bitcoin protocols with probabilistic logic programming., in: PLP@ ILP, 2018, pp. 49–61.

[R54] D. Sheehan, R. Gleasure, J. Feller, P. O'Reilly, S. Li, J. Cristiforo, Does miner pooling impact bitcoin's ability to stay decentralized?, in: Proceedings of the 13th International Symposium on Open Collaboration, 2017, pp. 1–4.

[R55] A. Judmayer, A. Zamyatin, N. Stifter, A. G. Voyiatzis, E. Weippl, Merged mining: Curse or cure?, in: Data Privacy Management, Cryptocurrencies and Blockchain Technology, Springer, 2017, pp. 316–333.

[R56] I. Eyal, The miner's dilemma, in: 2015 IEEE Symposium on Security and Privacy, IEEE, 2015, pp. 89–103.

[R57] M. Atzori, Blockchain technology and decentralized governance: Is the state still necessary?, Available at SSRN 2709713.

[R58] M. Conti, E. S. Kumar, C. Lal, S. Ruj, A survey on security and privacy issues of bitcoin, IEEE Communications Surveys & Tutorials 20 (4) (2018) 3416–3452.

[R59] Y. Velner, J. Teutsch, L. Luu, Smart contracts make bitcoin mining pools vulnerable, in: International Conference on Financial Cryptography and Data Security, Springer, 2017, pp. 298–316.

[R60] W. Wang, D. T. Hoang, Z. Xiong, D. Niyato, P. Wang, P. Hu, Y. Wen, A survey on consensus mechanisms and mining management in blockchain networks, arXiv preprint arXiv:1805.02707 (2018) 1–33.

[R61] A. Biryukov, D. Dinu, D. Khovratovich, Fast and tradeoff-resilient memory-hard functions for cryptocurrencies and password hashing., IACR Cryptology ePrint Archive 2015 (2015) 430.

[R62] A. M. Antonopoulos, Mastering Bitcoin: unlocking digital cryptocurrencies, " O'Reilly Media, Inc.", 2014.

[R63] I. Eyal, E. G. Sirer, Majority is not enough: Bitcoin mining is vulnerable, in: International conference on financial cryptography and data security, Springer, 2014, pp. 436–454.

[R64] P. Daian, I. Eyal, A. Juels, E. G. Sirer, Piecework: Generalized outsourcing control for proofs of work, in: International Conference on Financial Cryptography and Data Security, Springer, 2017, pp. 182–190.

[R65] G. Karame, On the security and scalability of bitcoin's blockchain, in: Proceedings of the 2016 ACM SIGSAC conference on computer and communications security, ACM, 2016, pp. 1861–1862.

[R66] W. Reijers, M. Coeckelbergh, The blockchain as a narrative technology: Investigating the social ontology and normative configurations of cryptocurrencies, Philosophy & Technology 31 (1) (2018) 103–130.

[R67] S. Park, A. Kwon, G. Fuchsbauer, P. Gaži, J. Alwen, K. Pietrzak, Spacemint: A cryptocurrency based on proofs of space, in: International Conference on Financial Cryptography and Data Security, Springer, 2018, pp. 480–499.

[R68] S. Samtani, V. Baliga, On monopolistic practices in bitcoin: a coded solution, Indian JL & Tech. 11 (2015) 106.

[R69] S. Dziembowski, Introduction to cryptocurrencies, in: Proceedings of the 22nd ACM SIGSAC Conference on Computer and Communications Security, 2015, pp. 1700–1701.

[R70] P. Tasca, C. J. Tessone, Taxonomy of blockchain technologies. principles of identification and classification, arXiv preprint arXiv:1708.04872.

[R71] P. K. Kaushal, A. Bagga, R. Sobti, Evolution of bitcoin and security risk in bitcoin wallets, in: 2017 International Conference on Computer, Communications and Electronics (Comptelix), IEEE, 2017, pp. 172–177.

[R72] Y. Sompolinsky, Y. Lewenberg, A. Zohar, Spectre: A fast and scalable cryptocurrency protocol., IACR Cryptology ePrint Archive 2016 (2016) 1159.

[R73] K. Dowd, M. Hutchinson, Bitcoin will bite the dust, Cato J. 35 (2015) 357.

[R74] K. Yeow, A. Gani, R. W. Ahmad, J. J. Rodrigues, K. Ko, Decentralized consensus for edge-centric internet of things: A review, taxonomy, and research issues, IEEE Access 6 (2017) 1513–1524.

[R75] A. Miller, A. Kosba, J. Katz, E. Shi, Nonoutsourceable scratch-off puzzles to discourage bitcoin mining coalitions, in: Proceedings of the 22nd ACM SIGSAC Conference on Computer and Communications Security, 2015, pp. 680–691.

[R76] A. E. Gencer, S. Basu, I. Eyal, R. Van Renesse, E. G. Sirer, Decentralization in bitcoin and ethereum networks, in: International Conference on Financial Cryptography and Data Security, Springer, 2018, pp. 439–457.

[R77] J. Yli-Huumo, D. Ko, S. Choi, S. Park, K. Smolander, Where is current research on blockchain technology?—a systematic review, PloS one 11 (10) (2016) e0163477.

[R78] A. Ray, M. Ventresca, H. Wan, A mechanism design approach to blockchain protocols, in: 2018 IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData), IEEE, 2018, pp. 1603–1608.

[R79] I. Eyal, A. E. Gencer, E. G. Sirer, R. Van Renesse, Bitcoin-ng: A scalable blockchain protocol, in: 13th {USENIX} symposium on networked systems design and implementation ({NSDI} 16), 2016, pp. 45–59.

[R80] M. Apostolaki, A. Zohar, L. Vanbever, Hijacking bitcoin: Routing attacks on cryptocurrencies, in: 2017 IEEE Symposium on Security and Privacy (SP), IEEE, 2017, pp. 375–392.

[R81] G. O. Karame, E. Androulaki, Bitcoin and blockchain security, Artech House, 2016.

[R82] Y. Liu, J. Ke, Q. Xu, H. Jiang, H. Wang, Decentralization is vulnerable under the gap game, IEEE Access 7 (2019) 90999–91008.

[R83] N. T. Courtois, P. Emirdag, Z. Wang, On detection of bitcoin mining redirection attacks, in: 2015 International Conference on Information Systems Security and Privacy (ICISSP), IEEE, 2015, pp. 98–105.

[R84] T. Neudecker, H. Hartenstein, Network layer aspects of permissionless blockchains, IEEE Communications Surveys & Tutorials 21 (1) (2018) 838–857.

[R85] J. Khan, To what extent can blockchain be used as a tool for community guidance, Edinburgh Student L. Rev. 3 (2016) 114.

[R86] U. W. Chohan, Cryptocurrencies and inequality, Notes on the 21st Century (CBRI).

[R87] Y.-Y. Hsieh, J.-P. J. Vergne, S. Wang, The internal and external governance of blockchain-basedorganizations: Evidence from cryptocurrencies, in: Bitcoin and Beyond (Open Access), Routledge, 2017, pp. 48–68.

[R88] R. Beck, C. Müller-Bloch, J. L. King, Governance in the blockchain economy: A framework and research agenda, Journal of the Association for Information Systems 19 (10) (2018) 1.

[R89] W. Zhang, Y. Yuan, Y. Hu, S. Huang, S. Cao, A. Chopra, S. Huang, A privacy-preserving voting protocol on blockchain, in: 2018 IEEE 11th International Conference on Cloud Computing (CLOUD), IEEE, 2018, pp. 401–408.

Appendix C. Interview Data collection and Analysis

We conducted semi-structured interviews following the guiding interview script [23]. This script served as the interview protocol to ensure coverage of all aspects of our study. These semi-structured interviews were transcribed in anonymized form. In some instances, the interview was recorded in the form of contemporaneous notes when the interviewee preferred not to be recorded. The note-taking process was primarily focused on capturing the views relevant to our research questions.

The transcripts and notes were analyzed by using qualitative methods, as described by Seaman (1999). The first step was to read the text and identify relevant content. This process was repetitive as analyzing more text reveled a pattern that iteratively refined the coding in the first step. To ease the process of text-analysis, we employed the Nvivo tool. This tool enabled us to organize code (annotations) into hierarchies.

In the second step, we assigned codes to the relevant content. The focus of this step was the adoption of terms used by interviewees rather than the interpretation of semantics. For example, we coded "Decentralization" and "Centralization" separately despite frequent use in the same context.

During the coding process, we grouped similar codes into clusters where possible. This process was aided by the Nvivo tool; the hierarchy view in the tool is shown in Figure C.14. Figure C.14 outlines the code clusters and individual codes with colors used in the data extraction process for interviews.

[23] Interview script is available at www.github.com/ashishrsai/centralization.

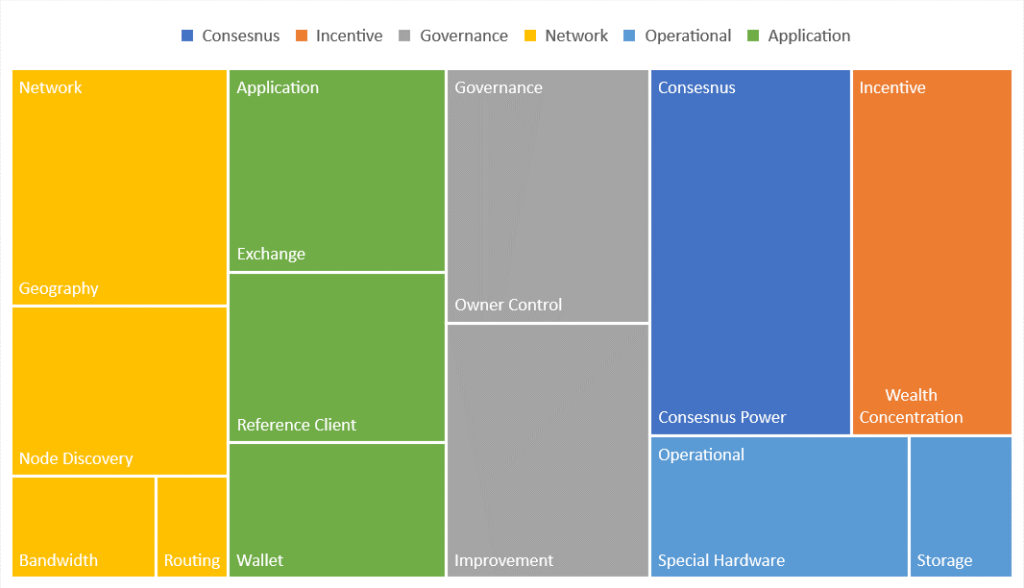

Figure C.14: Hierarchy View of Interview Coding