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Academics

Princeton University Princeton, NJ
Assistant Professor of Computer Science Sept 2007—present

New York University, Courant Institute New York, NY
Ph.D. in Computer Science Sept 2007
Thesis title: *Democratizing Content Distribution*
Visited **Stanford University**, September 2005—August 2007
Advisor: David Mazières ; GPA: 4.0/4.0

M.S. in Computer Science May 2005
Advisor: David Mazières ; GPA: 4.0/4.0

Massachusetts Institute of Technology Cambridge, MA
M.Eng. in Electrical Engineering and Computer Science June 2002
Thesis title: *A Peer-to-Peer Anonymizing Network Layer*
Advisor: Robert Morris ; GPA: 5.0/5.0

S.B. in Computer Science, Minor in Political Science June 2001
Thesis title: *An Anonymous Communications Channel for the Free Haven Project*
Advisor: Ron Rivest ; GPA: 4.9/5.0

Wyoming Valley West High School Plymouth, PA
Graduated Class Valedictorian (1/314), June 1997. National Merit Finalist, Advanced Placement Scholar with Distinction, Congressional Award (Silver and Bronze).

Interests Distributed systems, security, and networking.

Current Research

2009–present **Services in the untrusted cloud.** Designing services that can use servers in public clouds (*i.e.*, third-party datacenters), yet provide privacy and security even in the face of curious or malicious cloud providers. SPORC [9], for example, provides a framework for building collaborative applications, such as online, real-time text editors. Cloud servers in SPORC store and order clients' encrypted operations, yet its clients use cryptographic integrity checks to detect if servers act maliciously (by adding, changing, dropping or reordering operations). Upon detecting faults, clients can switch to alternative servers and automatically merge (by reordering and transforming) any divergent state, and the system supports dynamic access control even in the face of concurrent membership changes. The work establishes the conceptual connection between operational transformation and fork consistency. Recent work builds on SPORC to much larger environments (such as online social networks), where the number of documents and friendship relationships, as well as the dynamism of those objects and relationships, are orders of magnitude larger.

2008–present **Service-centric networks.** Developing a new end-host stack and supporting network architecture, Serval [76] [70] [1], that makes it easier for hosts and networked services to manage and even capitalize on multiplicity (in service replicas, host interfaces, and network paths) and dynamism (due to replica failure and recovery, service migration, and client mobility). A key abstraction of our stack is service-level anycast with connection affinity, provided by a new service access layer

that sits between the network and transport layers. Applications communicate on opaque service names that “late bind” to a service instance via anycast, while maintaining affinity to the instance across mobility, migration, and interface failures. A connection can send traffic over multiple interfaces and paths, capitalizing on multi-homed hosts and multipath routing [56]. <http://www.serval-arch.org/>

2008–present

Virtual worlds. Researching and building Internet-scale virtual worlds, with a focus on scalability, extensibility, security, and federation. Ongoing work on Sirakata leverages geometric- and physical-based constraints, using approaches from computer graphics and computational geometry, to provide scalable and efficient inter-object and inter-space communication, object discovery, world segmentation, distributed storage and caching, and dynamic content delivery [61] [60] [69] [55] [57]. <http://www.sirikata.com/>

2007–present

Fault-tolerant datacenter services. As commercial systems have grown to Internet scale, they have often sacrificed stronger consistency semantics due to their perceived costs and lack of scalability. Yet stronger consistency guarantees make systems easier for a programmer to reason about and provide users with more expected behavior (i.e., “what you write is what you’ll subsequently get”). Toward this end, we have been developing developed several key-value storage systems that challenge the notion of a strict tradeoff between consistency and performance. These systems include the CRAQ system (Chain Replication with Apportioned Queries), which achieves higher throughput for common cloud workloads for the a slightly scale of consistency (from eventual to linearizability) [16], and is particularly well-suited for read-heavy workloads.

The COPS system [4] provides an “always-on” experience where operations always complete with low latency, even for geo-replicated, distributed data storage. But unlike most previous systems that sacrificed stronger consistency, we show that COPS provides *causal consistency with convergent conflict handling*, or *causal+*—the strongest model achieved under these constraints. A key contribution of COPS is its scalability, which can enforce causal dependencies between keys stored across an entire cluster, rather than a single server like previous systems. The central approach in COPS is tracking and explicitly checking whether causal dependencies between keys are satisfied in the local cluster before exposing writes. Further, in COPS-GT, we introduce get transactions in order to obtain a consistent view of multiple keys without locking or blocking.

In the Byzantine (malicious) setting, Prophecy introduces a new form of consistency called *delay-once consistency* for replicated state machines [14]. While slightly weaker than linearizability, Prophecy can achieve this consistency at a cost almost identical to fully unreplicated reads for read-mostly workloads. Finally, we are exploring “commensal cuckoo” algorithms [33] [2] that securely partition large numbers of nodes (of which a certain fraction may be Byzantine) into small groups, such that each group has a quorum of correct nodes, even under malicious “leave-and-join” attacks.

2006–present

Software-defined networking. Design and implementation contributions to the clean-slate SANE [20] and backwards-compatible Ethane [18] [15] enterprise network architecture. Ethane network switches provide connectivity through on-demand virtual circuits, yet enforce security policies on a per-flow basis through centrally-managed, atomic, auditable name bindings. Multi-month deployment at Stanford served hundreds of both wired and wireless hosts. Technology is now being commercialized by Nicira Networks and supported by most major switch vendors as part of the OpenFlow Switch Consortium and the Open Networking Foundation.

DIFANE looks at preserving the capabilities of Ethane-style networks (with fine-grained administrative policies on flows), while decentralizing the processing of new flows and keeping all packet processing completely in the dataplane [10]. DIFANE can be readily implemented with commodity switch hardware, since all dataplane functions can be expressed in terms of wildcard rules that perform simple actions on matching packets.

Ongoing work develops a programming language, Frenetic [36] [7], and run-time environment for managing and controlling programmable networks, such as those managed via the low-level OpenFlow protocol. Uses ideas originally developed in the functional programming community.

2005–present

Replica selection and anycast. Designed and built OASIS, an infrastructure for locality- and load-based server selection among replicated Internet services [21] [63]. OASIS demonstrates

using disparate services to perform (potentially error-prone) network locality measurement, and it scalably manages their state information. OASIS was in production use between Nov. 2005–July 2009, handling thousands of replicas from more than a dozen distributed services. Background measurement studies examines the geographic locality of IP prefixes [23] and the efficacy of virtual coordinate systems [44].

Its successor, DONAR [11], demonstrates a constraint-based optimization that supports flexible service policies, as opposed to heuristics or centralized solutions. DONAR robustly decomposes the selection process into a decentralized algorithm. Deployed since Nov. 2009 at a dozen commercial PoPs worldwide, DONAR provides server selection (through DNS or HTTP) for a portion of CoralCDN’s traffic, as well as for services on the Measurement Lab testbed, an open-source platform co-sponsored by the New America Foundation, PlanetLab, and Google. This includes use by the FCC for its Consumer Broadband Test. <http://www.donardns.org/>

2002–present

Content distribution and peer-to-peer systems. Conceived and led the Coral Project. Designed and built an Internet-scale, self-organizing web-content distribution network: CoralCDN [29] [13] uses a network of cooperating DNS redirectors and HTTP proxies, backed by a decentralized indexing infrastructure [46], to allow oblivious clients to transparently download content from nearby servers, while avoiding distant or heavily-loaded ones. CoralCDN has been in production use on 300-400 PlanetLab servers since March 2004, currently receiving around 50 million HTTP requests from more than 2 million clients per day [3], serving several terabytes of data. <http://coralcdn.org/>

Research on the conceptual design of untrusted peer-assisted CDNs [40] [39] [17] [5], employed *price theory* to study how peer demand can be efficiently matched to available supply. This work characterizes the efficiency and robustness gains that are enabled by price-based multilateral exchange, as opposed to bilateral exchanges such as BitTorrent.

To scale beyond CoralCDN’s limits, we also built a browser-based P2P-CDN, Firecoral [38]. Firecoral enables mutually-distrustful users to “share” their browser caches, yet ensures the authenticity of content and enables users to preserve privacy by expressing flexible content sharing policies. Beta release saw around 2000 installations.

2000–present

Anonymity systems. Designed and implemented Tarzan [30] [48], a peer-to-peer anonymous IP network layer that is strongly resistant to traffic analysis. Tarzan helped protect against Sybil attacks through the selection of neighbors in a constrained and verifiable manner. Helped design Free Haven, a distributed system for the anonymous publishing, storage, and retrieval of information [51] [52] [65].

Recent work on Cloud-based Onion Routing (COR) explores how to improve performance compared to more peer-to-peer designs (i.e., Tor), better inhibit censorship, and create a market for anonymity and censorship-resistance services [68] [34].

Prior Research

2006–2007

IP analytics. By instrumenting CoralCDN, used active web content (javascript, Java applets, etc.) to measure and analyze the characteristics of over 7 million clients with respect to “edge technologies” (NATs, proxies, DNS, and DHCP) [19]. Results quantify how Internet services can use IP addresses to identify clients and enforce access-control decisions. Commercialized historical and real-time techniques for proxy detection and IP geolocation; acquired by Quova, Inc. in Nov. 2006.

2005–2007

Reliable email. Designed and implemented the security and privacy protections in Re:, an email acceptance system that leverages social proximity for automated whitelisting [22], using private matching [27]. Subsequent analysis of privacy for social networks led to more efficient protocols based only on symmetric-key operations (or achieving stronger properties using bilinear maps) [41].

2003-2005

Secure distributed file systems and file dissemination. With a focus on settings with mutually-distrustful clients, Shark [24] provides a distributed file system that improves scalability and performance through cooperative reads and semantic chunking, using Coral’s indexing layer to locate

files. Yet Shark preserves traditional semantics, manageability, and security. Other research provides integrity guarantees for large files encoded with rateless erasure codes, via a homomorphic hash function that can verify downloaded blocks on-the-fly [28].

2000–2010 **Privacy-preserving multiparty computation.** Developed cryptographic protocols for private matching, which computes the set intersection between two or more parties' inputs [27] [58]. PM uses the properties of homomorphic encryption to privately evaluate a polynomial representation of input sets. Subsequent work led to improved constructions for private keyword search based on oblivious pseudorandom functions [25], as well as explicit consideration of detecting graph proximity for social networks [41].

More recent work looked at greatly improving performance for privacy-preserving data aggregation between large numbers of participants. Techniques more logically centralize functionality, but maintains both strong participant and data privacy by dividing trust assumptions between two or more non-colluding service providers [12].

Work experience

8/07–present **Assistant Professor.** Princeton University, Princeton, NJ.
3/06–11/06 **Co-founder.** Illuminics Systems, Mountain View, CA. Acquired by Quova, Inc.
9/05–8/07 **Research Staff.** Stanford University (SCS Group), Stanford, CA.
5/05–8/05 **Research Assistant.** University of California, Berkeley, Berkeley, CA.
9/02–5/05 **Research Assistant.** New York University (SCS Group), New York, NY.
5/03–8/03 **Research Associate.** HP Labs (Trusted Systems Lab), Princeton, NJ.
9/01–6/02 **Research Assistant.** MIT LCS (PDOS Group), Cambridge, MA.
5/01–8/01 **Research Intern.** InterTrust Technologies (STAR Lab), Santa Clara, CA.
6/00–8/00 **Advanced R&D Intern.** Zero-Knowledge Systems, Montreal, Quebec.
6/99–8/99 **Developer (Intern).** Sun Microsystems (HPC Group), Burlington, MA.
6/98–8/98 **Developer (Intern).** Cognex Corporation, Natick, MA.
9/96–5/97 **System Administrator.** Wilkes University (Simulation Lab), Wilkes-Barre, PA.
6/95–8/95 **Intern.** Michigan State University (HPC Group), East Lansing, MI.

Technical Consulting

6/11–present **Institute for Defense Analyses (IDA)** Alexandria, VA.
6/11–present **Intelligent Automation, Inc.** Rockville, MD. Helping design survivable and secure content distribution network for dynamic tactical environments, as part of AFOSR project.
3/09–8/10 **CloudFlare.** Bay Area, CA. Advised security startup that protects websites from malicious online behavior, by proxying and filtering Web traffic while providing CDN and DNS service.
8/07–9/08 **NetFlix, Inc.** Los Gatos, CA. Helped design content distribution network and data-center architecture to support online distribution of short and full-length videos.
11/06–09/07 **Quova, Inc.** Mountain View, CA. Helped design and build GeoPoint v6.0, an IP geolocation and analytics platform, which incorporated architectural and technical aspects of illuminati research.
Legal consulting and expert references available upon request.

Advising

Current Advisees

PostDoc Erik Nordström

Ph.D.	Matvey Arye, Aaron Blankstein, Prem Gopalan, Rob Kiefer, Xiaozhou Li, Wyatt Lloyd, Sidhartha Sen, David Shue, Jeff Terrace
Masters	Nick Jones
Undergrad	Michael Franklin, Amy Ousterhout

Ph.D. Committee

Reader	Changhoon Kim (2008), Haakon Ringberg (2010), Yi Wang (2010), Minlan Yu (2011), Anirudh Badam (2011), Wonho Kim (2011), Ewen Cheslack-Postava (Stanford)
Non-Reader	Elliott Karpilovsky (2008), William Josephson (2010), Sunghwan Ihm (2011), Yaping Zhu (2011), Joe Wenjie Jiang (2011)

Previous Advisees

PostDoc	Steven Ko (2009–2010, now: Asst Professor, SUNY-Buffalo)
Masters	Robert Soule (2004, NYU), Jeff Borden (2004, NYU), Justin Pettit (2007, Stanford), Muneeb Ali (2011), Matvey Arye (2011)
Undergrad	NYU: Kevin Shanahan, Ed Kupershlak (2003–2004); Stanford: Jeffrey Spehar (2006–2007); Princeton: Hal Laidlaw, Mark Spear (2007–2008); Newton Allen, Hao Eric Liu, Andrew Schran, Sean Stern, Jennifer Yu (2008–2009); Paul Cavallaro, Dmitri Garbuzov, Andrew Gwozdz, Sajid Mehmood, Chris Rucinski (2009–2010); Kay Ousterhout, Patrick Wendell (2009–2011); Gabrielle Chen, Eddy Ferreira, Emily Lancaster, Brandon Podmayersky Zhihong Xu (2010–2011)

Teaching

9/11–1/12	Instructor. COS-518—Advanced Computer Systems, Princeton. (30 students)
2/11–6/11	Instructor. COS-461—Computer Networks, Princeton. (62 students)
9/10–1/11	Instructor. COS-597b—Grad Seminar: Future Datacenter Networks and Systems, Princeton. (20 students)
2/10–6/10	Instructor. COS-461—Computer Networks, Princeton. (49 students)
9/09–1/10	Instructor. COS-518—Advanced Operating Systems, Princeton. (8 students)
2/09–6/09	Instructor. COS-461—Computer Networks, Princeton. (40 students)
9/08–1/09	Instructor. COS-597b—Grad Seminar: Systems and Networking for Virtual Worlds, Princeton. (8 students)
9/07–1/08	Instructor. COS-518—Advanced Operating Systems, Princeton. (18 students)
1/04–5/04	Teaching Assistant, Lab Instructor. V22.0480—Computer Networks, NYU.
2/02–5/02	Teaching Assistant. 6.033—Computer System Engineering, MIT.
2/01–5/01	Teaching Assistant. 6.033—Computer System Engineering, MIT.

Service

9/10–8/13	Committee on Grading, Princeton University, Princeton. NJ.
9/10–present	Academic Advisor and Faculty Fellow. Princeton A.B. Majors (Freshman and Sophomores), Wilson College, Princeton, NJ.
9/09–present	Departmental Colloquia Organizer. Princeton Computer Science, Princeton, NJ.
9/08–5/10	Freshman Academic Advisor. Princeton B.S.E. Majors, Wilson College, Princeton, NJ.
2/08–05/11	Academic Advisor. Princeton Computer Science B.S.E Majors, Class of 2011, Princeton, NJ.
2/08–present	Faculty Associate. Princeton Center for Information Technology Policy, Princeton, NJ.

9/07–5/08 **Faculty Fellow.** Princeton Center for Jewish Life, Princeton, NJ.
 5/03–5/05 **Founder and Organizer.** NYU Systems Reading Group, New York, NY.
 2/04–5/05 **Faculty Representative.** NYU Courant Student Organization, New York, NY.
 9/01–5/02 **Co-organizer.** MIT Applied Security Reading Group, Cambridge, MA.
 9/97–5/02 **President, VP, Winter School Organizer, Member.** MIT Outing Club, Cambridge, MA

Professional activities

Program chair HotDep '11 (co-chair), IPTPS '10 (co-chair), NSDI '09 (poster chair)
 Program comm. NSDI '12, CCS '11, FOCI '11, SIGCOMM '11, HotOS '11, OSDI '10, NSDI '10, SOSP '09, LADIS '09, USENIX Technical '09, IEEE Security and Privacy '09, NSDI '09, IPTPS '09, ROADS '09, CCS '08, CT-RSA '08, IPTPS '08, WORLDS '06, UPGRADE-CDN '06, IRIS Student P2P Workshop '03
 Funding Panels NSF CISE Computer Systems Research (CSR) '10, NSF CISE Network Science and Engineering (NetSE) '09
 External reviews NSDI '11, NSDI '08, NSDI '07, LATIN '06, HotNets '05, EUROCRYPT '05, Usenix Technical '05, ISC '04, CRYPTO '04, IPDPS '04, INFOCOM '04, CCS '03, SOSP '03, ISC '03, PODC '03, EUROCRYPT '03, WPES '02
 Journal reviews Transactions of Networking (TON), Transactions on Computer Systems (TOCS), Journal of Computer Security, Journal of Parallel and Distributed Computing (JPDC), Handbook of Internet Security - P2P Security (Wiley & Sons), Computer Journal

Honors

DARPA Computer Science Study Group (CSSG) member, 2011 (13 assistant professors chosen across computer science)
 Alfred P. Sloan Research Fellowship, 2011
 CAREER Award (CSR), National Science Foundation, 2009
 Young Investigator Award, Office of Naval Research, 2009 (15 across science and engineering)
 E. Lawrence Keyes, Jr./Emerson Electric Co. Faculty Advancement Award, Princeton School of Engineering and Applied Science (SEAS), 2009

 Nominated by NYU for ACM Doctoral Dissertation award, 2008
 Janet Fabri Prize, NYU Computer Science, 2008 (for best Ph.D. dissertation)
 Henning Biermann Award, NYU Computer Science, 2005 (for outstanding education and service)

 NDSEG (DoD) Graduate Fellow, 2002-2005
 NYU McCracken Fellow, 2002-2006

 Award paper (invited to SIGOPS OSR), LADIS 2011 [33].
 Highest-ranked paper, SIGCOMM 2007 [18]. Fast-tracked to IEEE/ACM Trans. Networking.
 Best demo award, WORLDS 2005 [21].
 Highest-ranked paper, EUROCRYPT 2004 [27].
 Award paper (invited to TISSEC), CCS 2002 [30].

 Awarded NSF Graduate Fellowship for 2002-2005
 Awarded Gordon Wu Fellowship (Princeton), 2001 ; Sterling Prize Fellowship (Yale), 2001
 Awarded Graduate Fellowships (U.C. Berkeley, Carnegie-Mellon, UCSD), 2001

 Coca-Cola Scholar, 1997-2001 ; Tylenol Scholar, 1997-1999 ; Big 33 Scholar, 1997-1998
 Member of Tau Beta Pi, 2000 ; Eta Kappa Nu, 2000 ; Sigma Xi, 2000 ; Order of Omega, 1999
 Congressional Award, Silver (1996) and Bronze (1993) medals

Honors by student research advisees

Facebook Ph.D. Fellowship, Finalist: Wyatt Lloyd, 2012
CRA Outstanding Undergrad Researcher: Zhihong Xu, Honorable Mention, 2012
Princeton Computer Science, Accenture Prize: Zhihong Xu, 2011
Princeton Computer Science, Accenture Prize: Brandon Podmayersky, 2011
Siebel Graduate Scholarship: Wyatt Lloyd (PhD), 2011
Siebel Graduate Scholarship: Nicholas Jones (MSE), 2011
Princeton School of Engineering, Calvin Dodd MacCraken Senior Project Award: Patrick Wendell, 2011
Princeton Computer Science, Senior Independent Work Prize: Patrick Wendell, 2011
NDSEG and NSF Graduate Fellowship: Patrick Wendell (as undergrad), 2011
Hertz and NSF Graduate Fellowship: Kay Ousterhout (as undergrad), 2011
CRA Outstanding Undergrad Researcher: Patrick Wendell, Winner (male), 2011
CRA Outstanding Undergrad Researcher: Kay Ousterhout, Honorable Mention, 2011
Google Anita Borg Memorial Scholarship: Kay Ousterhout, 2011
Princeton Computer Science, Accenture Prize: Kay Ousterhout, 2010
Google Ph.D. Fellowship in Fault Tolerance: Siddhartha Sen, 2009-2012
Princeton Computer Science, Senior Thesis Prize: Andrew Schran, 2009

Refereed journal and conference publications

- [1] Erik Nordstrom, David Shue, Prem Gopalan, Rob Kiefer, Matvey Arye, Steven Ko, Jennifer Rexford, and **Michael J. Freedman**. Serval: An end-host stack for service-centric networking. In *Proc. 9th Symposium on Networked Systems Design and Implementation (NSDI 12)*, San Jose, CA, April 2012.
- [2] Siddhartha Sen and **Michael J. Freedman**. Commensal Cuckoo: Secure group partitioning for large-scale services. *ACM SIGOPS Operating System Review*, January 2012.
- [3] Patrick Wendell and **Michael J. Freedman**. Going Viral: Flash crowds in an open CDN. In *Proc. 11th ACM SIGCOMM Conference on Internet Measurement (IMC 11)*, Berlin, Germany, November 2011.
- [4] Wyatt Lloyd, **Michael J. Freedman**, Michael Kaminsky, and David G. Andersen. Don't settle for eventual: Scalable causal consistency for wide-area storage with COPS. In *23rd ACM Symposium on Operating Systems Principles (SOSP 11)*, Cascais, Portugal, October 2011.
- [5] Christina Aperjis, **Michael J. Freedman**, and Ramesh Johari. Bilateral and multilateral exchanges for peer-assisted content distribution. *IEEE/ACM Transactions on Networking*, 19(5):1290–1303, October 2011.
- [6] Siddhartha Sen, Sunghwan Ihm, Kay Ousterhout, and **Michael J. Freedman**. Bridging the theory-practice gap in multi-commodity flow routing (brief announcement). In *25th International Symposium on Distributed Computing (DISC 11)*, Rome, Italy, September 2011.
- [7] Nate Foster, Rob Harrison, **Michael J. Freedman**, Christopher Monsanto, Jennifer Rexford, Alec Story, and David Walker. Frenetic: A network programming language. In *Proc. ACM SIGPLAN International Conference on Functional Programming (ICFP 11)*, Tokyo, Japan, September 2011.
- [8] Wyatt Lloyd and **Michael J. Freedman**. Coercing clients into facilitating failover: Transparent recovery for object delivery services. In *41st IEEE/IFIP International Conference on Dependable Systems and Networks (DSN 11), Dependable Computing and Communication Symposium (DCCS) track*, Hong Kong, China, June 2011.

- [9] Ariel J. Feldman, William P. Zeller, **Michael J. Freedman**, and Edward W. Felten. SPORC: Group collaboration using untrusted cloud resources. In *Proc. 9th Symposium on Operating Systems Design and Implementation (OSDI 10)*, Vancouver, BC, October 2010.
- [10] Minlan Yu, Jennifer Rexford, **Michael J. Freedman**, and Jia Wang. Scalable flow-based networking with DIFANE. In *Proc. ACM SIGCOMM Conference*, pages 351–362, New Delhi, India, August 2010.
- [11] Patrick Wendell, Joe Wenjie Jiang, **Michael J. Freedman**, and Jennifer Rexford. DONAR: Decentralized server selection for cloud services. In *Proc. ACM SIGCOMM Conference*, pages 231–242, New Delhi, India, August 2010.
- [12] Benny Applebaum, Haakon Ringberg, **Michael J. Freedman**, Matthew Caesar, and Jennifer Rexford. Collaborative, privacy-preserving data aggregation at scale. In *Proc. 10th Privacy Enhancing Technologies Symposium (PETS 10)*, pages 56–74, Berlin, Germany, July 2010.
- [13] **Michael J. Freedman**. Experiences with CoralCDN: A five-year operational view. In *Proc. 7th Symposium on Networked Systems Design and Implementation (NSDI 10)*, pages 95–110, San Jose, CA, April 2010.
- [14] Siddhartha Sen, Wyatt Lloyd, and **Michael J. Freedman**. Prophecy: Using history for high-throughput fault tolerance. In *Proc. 7th Symposium on Networked Systems Design and Implementation (NSDI 10)*, pages 345–360, San Jose, CA, April 2010.
- [15] Martin Casado, **Michael J. Freedman**, Justin Pettit, Jianying Luo, Natasha Gude, Nick McKeown, and Scott Shenker. Rethinking enterprise network control. *IEEE/ACM Trans. Networking*, 17(4):1270–1283, 2009.
- [16] Jeff Terrace and **Michael J. Freedman**. Object storage on CRAQ: High-throughput chain replication for read-mostly workloads. In *Proc. USENIX Annual Technical Conference*, pages 143–158, San Diego, CA, June 2009.
- [17] Christina Aperjis, **Michael J. Freedman**, and Ramesh Johari. Peer-assisted content distribution with prices. In *Proc. 4th ACM SIGCOMM Conference on emerging Networking Experiments and Technologies (CoNext 08)*, Madrid, Spain, December 2008.
- [18] Martin Casado, **Michael J. Freedman**, Justin Pettit, Jianying Luo, Nick McKeown, and Scott Shenker. Ethane: Taking control of the enterprise. In *Proc. ACM SIGCOMM Conference*, pages 1–12, Kyoto, Japan, August 2007.
- [19] Martin Casado and **Michael J. Freedman**. Peering through the shroud: The effect of edge opacity on IP-based client identification. In *Proc. 4th Symposium on Networked Systems Design and Implementation (NSDI 07)*, pages 173–186, Cambridge, MA, April 2007.
- [20] Martin Casado, Tal Garfinkle, Aditya Akella, **Michael J. Freedman**, Dan Boneh, Nick McKeown, and Scott Shenker. SANE: A protection architecture for enterprise networks. In *Proc. 15th USENIX Security Symposium*, pages 137–151, Vancouver, BC, August 2006.
- [21] **Michael J. Freedman**, Karthik Lakshminarayanan, and David Mazières. OASIS: Anycast for any service. In *Proc. 3rd Symposium on Networked Systems Design and Implementation (NSDI 06)*, pages 129–142, San Jose, CA, May 2006.
- [22] Scott Garriss, Michael Kaminsky, **Michael J. Freedman**, Brad Karp, David Mazières, and Haifeng Yu. Re: Reliable email. In *Proc. 3rd Symposium on Networked Systems Design and Implementation (NSDI 06)*, pages 297–310, San Jose, CA, May 2006.
- [23] **Michael J. Freedman**, Mythili Vutukuru, Nick Feamster, and Hari Balakrishnan. Geographic locality of IP prefixes. In *Proc. 5th ACM SIGCOMM Conference on Internet Measurement (IMC 05)*, pages 153–158, Berkeley, CA, October 2005.
- [24] Siddhartha Annapureddy, **Michael J. Freedman**, and David Mazières. Shark: Scaling file servers via cooperative caching. In *Proc. 2nd Symposium on Networked Systems Design and Implementation (NSDI 05)*, pages 129–142, Boston, MA, May 2005.

- [25] **Michael J. Freedman**, Yuval Ishai, Benny Pinkas, and Omer Reingold. Keyword search and oblivious pseudorandom function. In *Proc. 2nd Theory of Cryptography Conference (TCC 05)*, pages 303–324, Cambridge, MA, February 2005.
- [26] Yevgeniy Dodis, **Michael J. Freedman**, Stanislaw Jarecki, and Shabsi Walfish. Versatile padding schemes for joint signature and encryption. In *Proc. 11th ACM Conference on Computer and Communications Security (CCS 04)*, pages 344–353, Washington, D.C., October 2004.
- [27] **Michael J. Freedman**, Kobbi Nissim, and Benny Pinkas. Efficient private matching and set intersection. In *Advances in Cryptology — EUROCRYPT 2004*, pages 1–19, Interlaken, Switzerland, May 2004.
- [28] Maxwell Krohn, **Michael J. Freedman**, and David Mazières. On-the-fly verification of rateless erasure codes for efficient content distribution. In *Proc. IEEE Symposium on Security and Privacy*, pages 226–240, Oakland, CA, May 2004.
- [29] **Michael J. Freedman**, Eric Freudenthal, and David Mazières. Democratizing content publication with Coral. In *Proc. 1st Symposium on Networked Systems Design and Implementation (NSDI 04)*, pages 239–252, San Francisco, CA, March 2004.
- [30] **Michael J. Freedman** and Robert Morris. Tarzan: A peer-to-peer anonymizing network layer. In *Proc. 9th ACM Conference on Computer and Communications Security (CCS 02)*, pages 193–206, Washington, D.C., November 2002.

Refereed workshop publications

- [31] Nate Foster, **Michael Freedman**, Rob Harrison, Christopher Monsanto, Mark Reitblatt, Jennifer Rexford, Alec Story, and David Walker. Language abstractions for software-defined networks (position paper). In *Proc. Workshop on Languages for Distributed Algorithms (LADA 12)*, January 2012.
- [32] Prem Gopalan, David Mimno, **Michael J. Freedman**, and David M. Blei. Online learning for mixed membership network models (extended abstract). New York, NY, October 2011.
- [33] Siddhartha Sen and **Michael J. Freedman**. Commensal Cuckoo: Secure group partitioning for large-scale services. In *5th Workshop on Large Scale Distributed Systems and Middleware (LADIS 11)*, Seattle, WA, September 2011.
- [34] Nicholas Jones, Matvey Arye, Jacopo Cesareo, and **Michael J. Freedman**. Hiding amongst the clouds: A proposal for cloud-based onion routing. In *USENIX Workshop on Free and Open Communications on the Internet (FOCI 11)*, San Francisco, CA, August 2011.
- [35] Peng Sun, Minlan Yu, **Michael J. Freedman**, and Jennifer Rexford. Identifying performance bottlenecks in CDNs through TCP-level monitoring. In *Proc. Workshop on Measurements Up the Stack (W-MUST 11)*, Toronto, Canada, August 2011.
- [36] Nate Foster, Rob Harrison, Matthew L. Meola, **Michael J. Freedman**, Jennifer Rexford, and David Walker. Frenetic: A high-level language for OpenFlow networks. In *Proc. ACM Workshop on Programmable Routers for Extensible Services of Tomorrow (PRESTO 10)*, Philadelphia, PA, November 2010.
- [37] Rodrigo Fonseca, **Michael J. Freedman**, and George Porter. Experiences with tracing causality in networked services. In *Proc. Internet Network Management Workshop / Workshop on Research on Enterprise Networking (INM/WREN 10)*, San Jose, CA, April 2010.
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- [41] **Michael J. Freedman** and Antonio Nicolosi. Efficient private techniques for verifying social proximity. In *Proc. 6th International Workshop on Peer-to-Peer Systems (IPTPS 07)*, Bellevue, WA, February 2007.
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- [43] **Michael J. Freedman**, Karthik Lakshminarayanan, Sean Rhea, and Ion Stoica. Non-transitive connectivity and DHTs. In *Proc. 2nd Workshop on Real, Large, Distributed Systems (WORLDS 05)*, pages 55–60, San Francisco, CA, December 2005.
- [44] Kevin Shanahan and **Michael J. Freedman**. Locality prediction for oblivious clients. In *Proc. 4th International Workshop on Peer-to-Peer Systems (IPTPS 05)*, pages 252–263, Ithaca, NY, February 2005.
- [45] Max Krohn and **Michael J. Freedman**. On-the-fly verification of erasure-encoded file transfers (extended abstract). In *Proc. 1st IRIS Student Workshop on Peer-to-Peer Systems*, Cambridge, MA, August 2003.
- [46] **Michael J. Freedman** and David Mazières. Sloppy hashing and self-organizing clusters. In *Proc. 2nd International Workshop on Peer-to-Peer Systems (IPTPS 03)*, pages 45–55, Berkeley, CA, February 2003.
- [47] Joan Feigenbaum, **Michael J. Freedman**, Tomas Sander, and Adam Shostack. Economic barriers with existing privacy technologies in e-commerce systems (position paper). In *Proc. Workshop on Economics and Information Security*, Berkeley, CA, May 2002.
- [48] **Michael J. Freedman**, Emil Sit, Josh Cates, and Robert Morris. Introducing Tarzan, a peer-to-peer anonymizing network layer. In *Proc. 1st International Workshop on Peer-to-Peer Systems (IPTPS 02)*, pages 121–129, Cambridge, MA, March 2002.
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Invited publications, technical reports, manuscripts, book chapters

- [53] Siddhartha Sen, Sunghwan Ihm, and **Michael J. Freedman**. LocalFlow: Scalable, optimal flow routing in datacenters. In submission, 2012.
- [54] David Shue, **Michael J. Freedman**, and Anees Shaikh. Performance isolation and fairness for multi-tenant cloud storage. In submission, 2012.
- [55] Ewen Cheslack-Postava, Tahir Azim, Behram F.T. Mistree, Daniel Reiter Horn, Jeff Terrace, Philip Levis, and **Michael J. Freedman**. A scalable server for 3D metaverses. In submission, 2012.

- [56] Matvey Arye, Erik Nordstrom, Robert Kiefer, Jennifer Rexford, and **Michael J. Freedman**. A provably-correct protocol for seamless communication with mobile, multi-homed hosts. In submission, 2011.
- [57] Jeffrey Terrace, Ewen Cheslack-Postava, Philip Levis, and **Michael J. Freedman**. Unsupervised conversion of 3d models for interactive metaverses. In submission, 2011.
- [58] **Michael J. Freedman**, Carmit Hazay, Kobbi Nissim, and Benny Pinkas. Efficient set intersection with simulation-based security. Accepted pending revision to IACR Journal of Cryptology, 2012.
- [59] **Michael J. Freedman**, Matvey Arye, Prem Gopalan, Steven Y. Ko, Erik Nordstrom, Jennifer Rexford, and David Shue. Service-centric networking with SCAFFOLD. Technical Report TR-885-10, Princeton University, Dept. Computer Science, September 2010.
- [60] Daniel Horn, Ewen Cheslack-Postava, Behram F.T. Mistree, Tahir Azim, Jeff Terrace, **Michael J. Freedman**, and Philip Levis. Scaling communication in virtual worlds with a physical metaphor. Technical Report CSTR 2010-01 5/11/10, Stanford University, Dept. Computer Science, 2010.
- [61] Daniel Horn, Ewen Cheslack-Postava, Tahir Azim, **Michael J. Freedman**, and Philip Levis. Scaling virtual worlds with a physical metaphor. *IEEE Pervasive Computing*, 8(3):50–54, July 2009.
- [62] Christina Aperjis, **Michael J. Freedman**, and Ramesh Johari. Comparing multilateral and bilateral exchange models for content distribution (invited). In *IEEE Information Theory Workshop*, Volos, Greece, June 2009.
- [63] **Michael J. Freedman**. Automating server selection with OASIS (invited). In *login: The USENIX Magazine*, pages 46–52, October 2006.
- [64] Roger Dingledine, **Michael J. Freedman**, David Molnar, and David Parkes. Reputation. In *Digital Government Civic Scenario Workshop*, Cambridge, MA, April 2003.
- [65] Roger Dingledine, **Michael J. Freedman**, and David Molnar. *Peer-to-Peer: Harnessing the Power of Disruptive Technology*, chapter Accountability, pages 271–340. O’Reilly, 2001.
- [66] Roger Dingledine, **Michael J. Freedman**, and David Molnar. *Peer-to-Peer: Harnessing the Power of Disruptive Technology*, chapter Free Haven, pages 159–190. O’Reilly, 2001.

Posters and demos

- [67] Siddhartha Sen and **Michael J. Freedman**. Security in peer-to-peer systems revisited (work-in-progress). In *23rd ACM Symposium on Operating Systems Principles (SOSP 11)*, Cascais, Portugal, October 2011.
- [68] Matvey Arye, Nicholas Jones, Jacopo Cesareo, and **Michael J. Freedman**. Cloud-based onion routing: Creating economies of scale for anonymity (poster). In *21st Conference on Computers, Freedom, and Privacy*, Washington, D.C., June 2011.
- [69] Philip Levis, **Michael J. Freedman**, Ewen Cheslack-Postava, Daniel Reiter Horn, Behram F. T. Mistree, Tahir Azim, Jeff Terrace, Bhupesh Chandra, and Xiaozhou Li. Sirikata: Design and implementation of a next generation metaverse (poster). In *13th Workshop on Hot Topics in Operating Systems (HotOS 11)*, Napa, CA, May 2011.
- [70] David Shue, Prem Gopalan, Matvey Arye, Erik Nordstrom, Steven Y. Ko, **Michael J. Freedman**, and Jennifer Rexford. A service access layer, at your service (demo). In *8th Symposium on Networked Systems Design and Implementation (NSDI 11)*, Boston, MA, March 2011.
- [71] Wyatt Lloyd, **Michael J. Freedman**, Michael Kaminsky, and David G. Andersen. Don’t settle for eventual: Stronger consistency for wide-area storage. In *8th Symposium on Networked Systems Design and Implementation (NSDI 11)*, Boston, MA, March 2011.
- [72] Siddhartha Sen, Sunghwan Ihm, Kay Ousterhout, and **Michael J. Freedman**. Localflow: Simple, local flow scheduling in data centers (poster). In *8th Symposium on Networked Systems Design and Implementation (NSDI 11)*, Boston, MA, March 2011.

- [73] **Michael J. Freedman**, Matvey Arye, Prem Gopalan, Steven Y. Ko, Erik Nordstrom, Jennifer Rexford, and David Shue. Dynamic service access with Serval (demo). In *10th GENI Engineering Conference*, San Juan, Puerto Rico, March 2011.
- [74] **Michael J. Freedman**, Matvey Arye, Prem Gopalan, Steven Y. Ko, Erik Nordstrom, Jennifer Rexford, and David Shue. Service-centric networking with SCAFFOLD (demo). In *9th GENI Engineering Conference*, Arlington, VA, November 2010.
- [75] Wyatt Lloyd and **Michael J. Freedman**. Coercing clients into facilitating failover: Transparent recovery for object delivery services (poster). In *9th Symposium on Operating Systems Design and Implementation (OSDI 10)*, Vancouver, B.C., October 2010.
- [76] **Michael J. Freedman**, Jennifer Rexford, Steven Y. Ko, Prem Gopalan, and David Shue. A SCAFFOLD for Wide-Area Distributed Services (poster). In *6th GENI Engineering Conference*, Salt Lake City, UT, November 2009.
- [77] Siddhartha Sen, Wyatt Lloyd, and **Michael J. Freedman**. Prophecy: Using history for high-throughput fault tolerance (work-in-progress). In *22nd ACM Symposium on Operating Systems Principles (SOSP 09)*, Big Sky, MT, October 2009.
- [78] Jeff Terrace and **Michael J. Freedman**. Bringing P2P to the Web: Security and privacy in the Firecoral network (poster). In *6th Symposium on Networked Systems Design and Implementation (NSDI 09)*, Boston, MA, April 2009.
- [79] Jeff Terrace and **Michael J. Freedman**. Query-anywhere chain replication (poster). In *2nd Workshop on Large-Scale Distributed Systems and Middleware (LADIS 08)*, Yorktown, NY, September 2008.
- [80] Siddhartha Sen, Wyatt Lloyd, and **Michael J. Freedman**. Scaling fault-tolerant systems with history (poster). In *2nd Workshop on Large-Scale Distributed Systems and Middleware (LADIS 08)*, Yorktown, NY, September 2008.
- [81] **Michael J. Freedman** and Martin Casado. Measuring the Internet's edge with Illuminati (poster and demo). In *7th USENIX Symposium on Operating Systems Design and Implementation (OSDI 06)*, *3rd Workshop on Real, Large, Distributed Systems (WORLDS 06)*, Seattle, WA, November 2006.
- [82] **Michael J. Freedman**, Karthik Lakshminarayanan, and David Mazières. Building a practical anycast service (demo). In *2nd Workshop on Real, Large, Distributed Systems (WORLDS 05)*, San Francisco, CA, December 2005.
- [83] Kevin Shanahan and **Michael J. Freedman**. Saccades: Locality prediction for oblivious clients (poster). In *2nd IRIS Student Workshop on Peer-to-Peer Systems*, Cambridge, MA, November 2004.
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- [85] **Michael J. Freedman**, Eric Freudenthal, and David Mazières. Democratizing content publication with Coral (demo). In *1st Symposium on Networked Systems Design and Implementation (NSDI 04)*, San Francisco, CA, March 2004.

Patents

- [86] Martin Casado and **Michael J. Freedman**. System and method of middlebox detection and characterization. United States Patent Application, Serial #2008/0072305 A1, March 2008.

Refereed conference presentations

- [87] Service-centric networking with the Serval network stack. DIMACS Workshop on Systems and Networking Advances in Cloud Computing, December 8 2011.

- [88] Collaborative, privacy-preserving data aggregation at scale. 10th Privacy Enhancing Technologies Symposium (PETS 10), July 21 2010.
- [89] Experiences with CoralCDN: A five-year operational view. 7th Symposium on Networked Systems Design and Implementation (NSDI 10), April 28 2010.
- [90] Prices are Right: Managing resources and incentives in peer-assisted content distribution. 7th International Workshop on Peer-to-Peer Systems (IPTPS 08), February 26 2008.
- [91] OASIS: Anycast for any service. 3rd Symposium on Networked Systems Design and Implementation (NSDI 06), May 9 2006.
- [92] Group therapy for systems: Using link attestations to manage failures. 5th International Workshop on Peer-to-Peer Systems (IPTPS 06), February 28 2006.
- [93] OASIS: Anycast for any service. CodeCon, February 10 2006.
- [94] Non-transitive connectivity and DHTs. 2nd Workshop on Real, Large, Distributed Systems (WORLDS 05), December 14 2005.
- [95] Keyword search and oblivious pseudorandom functions. 2nd Theory of Cryptography Conference (TCC 05), February 11 2005.
- [96] Efficient private matching and set intersection. Advances in Cryptology — EUROCRYPT 2004, May 3 2004.
- [97] Democratizing content distribution with Coral. 1st Symposium on Networked Systems Design and Implementation (NSDI 04), March 30 2004.
- [98] Efficient set intersection for privacy-preserving data mining. DIMACS Privacy-Preserving Data Mining, March 15 2004.
- [99] Sloppy hashing and self-organizing clusters. 2nd International Workshop on Peer-to-Peer Systems (IPTPS 03), February 20 2003.
- [100] Tarzan: A peer-to-peer anonymizing network layer. 9th ACM Conference on Computer and Communications Security (CCS 02), November 20 2002.
- [101] The case for network-layer, peer-to-peer anonymization. 1st International Workshop on Peer-to-Peer Systems (IPTPS 02), March 7 2002.
- [102] Privacy engineering in digital rights management systems. ACM Workshop in Security and Privacy in Digital Rights Management (DRM 01), November 5 2001.

Invited conference presentations and panels

- [103] Next technical steps (panel). Free and Open Communication on the Internet Workshop, February 24 2011.
- [104] Stop building distributed services with a decoupled host-centric network. Vancouver Systems Colloquium (following OSDI' 10), October 7 2010.
- [105] Meru: A system architecture for Internet-scale virtual worlds. NSF Workshop on Future of Research in Computer Games and Virtual Worlds, September 23 2010.
- [106] Make CDNs work for you: Measuring the Internet's edge with Illuminati (talk and panel). NY Systems/Networking Summit, November 17 2006.
- [107] Lessons from PlanetLab (panel). WORLDS, November 5 2006.
- [108] Supporting clients 24/7: On service deployment and development. PlanetLab Workshop, April 1 2004.
- [109] Accountability and resource management in peer-to-peer systems. O'Reilly Peer-to-Peer Conference, February 16 2001.

Other presentations

- [110] Software-defined networking for services. SDN Meetup, Organized by Cisco Systems, December 19 2011.
- [111] New abstractions for managing networked services. Harvard University, December 14 2011.
- [112] Service-centric networking with a new service access layer. Qualcomm, March 21 2011.
- [113] SPORC: Group collaboration using untrusted cloud resources (work-in-progress). 10th Privacy Enhancing Technologies Symposium (PETS 10), July 21 2010.
- [114] Building a service-centric network with SCAFFOLD. Stanford, Network Seminar, January 14 2010.
- [115] Building a service-centric network with SCAFFOLD. HP Labs, January 13 2010.
- [116] High-throughput replicated services with strong robustness guarantees. EPFL, August 14 2009.
- [117] High-throughput replicated services with strong robustness guarantees. ETH Zurich, August 10 2009.
- [118] Experiences with CoralCDN: A five-year operational view. Microsoft Research, March 13 2009.
- [119] An overview of datacenter-focused systems projects. Facebook, December 12 2008.
- [120] Peer-assisted content distribution with prices. Yahoo! Research, December 11 2008.
- [121] Democratizing content distribution. U. Hawaii, July 11 2008.
- [122] The role of prices in peer-assisted content distribution. Princeton/Supelec/Alcatel-Lucent Workshop on Wireless Communications and Networks, February 4 2008.
- [123] P2P-CDNs: Content distribution via access links. PRISM Center for Networks, Science, and Applications Workshop, December 6 2007.
- [124] Towards peer-assisted content distribution. NEC Labs, November 28 2007.
- [125] Democratizing content distribution. New York University, April 27 2007.
- [126] Democratizing content distribution. University of California, San Diego, April 25 2007.
- [127] Democratizing content distribution. Intel Research–Berkeley, April 23 2007.
- [128] Democratizing content distribution. University of Washington, April 19 2007.
- [129] Democratizing content distribution. University of California, Los Angeles, April 17 2007.
- [130] Democratizing content distribution. Carnegie-Mellon University, April 9 2007.
- [131] Democratizing content distribution. Microsoft Research, Silicon Valley Center, April 2 2007.
- [132] Democratizing content distribution. Princeton University, March 29 2007.
- [133] Democratizing content distribution. Stanford University, March 22 2007.
- [134] Democratizing content distribution. Duke University, March 19 2007.
- [135] Democratizing content distribution. Massachusetts Institute of Technology, March 15 2007.
- [136] Democratizing content distribution. Cornell University, March 13 2007.
- [137] Democratizing content distribution. Brown University, March 8 2007.
- [138] Democratizing content distribution. Palo Alto Research Center, March 5 2007.
- [139] Democratizing content distribution. University of Texas, Austin, March 1 2007.
- [140] Democratizing content distribution. Yale University, February 15 2007.
- [141] Democratizing content distribution. Columbia University, February 14 2007.
- [142] RE: Fighting spam with reliability and privacy. Princeton, Systems Seminar, November 20 2006.
- [143] RE: Fighting spam with reliability and privacy. Cornell, Security Seminar, November 15 2006.

- [144] RE: Reliable Email. Georgia Tech, Network Research Seminar, October 11 2006.
- [145] RE: Reliable Email. Microsoft Research, Silicon Valley Center, July 19 2006.
- [146] Illuminating the shadows of the Internet. Quova, Inc., June 28 2006.
- [147] OASIS: Anycast for any service. Xeros Palo Alto Research Center, February 22 2006.
- [148] Privacy-preserving protocols through polynomial encodings. U.C. Berkeley, Theory Seminar, February 13 2006.
- [149] Privacy-preserving protocols through polynomial encodings. UCLA, January 24 2006.
- [150] Shark: Scaling file servers via cooperative caching. ICSI Seminar, June 15 2005.
- [151] The design and deployment of Coral, an open peer-to-peer content distribution network. U.C. Berkeley, Systems Seminar, September 13 2004.
- [152] Democratizing content distribution with Coral. O'Reilly Foo Camp, September 11 2004.
- [153] Democratizing content distributing with Coral. Columbia University, Systems Seminar, March 25 2004.
- [154] Private matching. CRYPTO '03 (rump session), August 18 2003.
- [155] Anonymous communication and the design of Tarzan. Virginia Tech, NOVA, November 20 2002.
- [156] Building a peer-to-peer anonymizing network layer. New York University, Public Design Workshop, September 13 2002.
- [157] Digital rights management and cryptographic privacy. MIT Network and Computer Security class, November 1 2001.
- [158] Accountability and resource management in P2P systems. Lotus Research, P2P Speaker's Series, May 2 2001.

Support

- **Michael J. Freedman** (PI) and Ed Felten, linked with Georgia Tech (Nick Feamster, PI) and Tor Project (Roger Dingledine, PI). Facilitating Free and Open Access to Information on the Internet. NSF: Trustworthy Computing: Large (#1111734). \$750K to Princeton, total of \$3M. 2011-2015.
- **Michael J. Freedman**. Geo-replicated datacenter storage. Intel Science & Technology Center – Cloud Computing (ISTC-CC). ~\$80K. 2011.
- **Michael J. Freedman**. Adaptive Network Architecture for Dynamic End-Points and Distributed Systems. DARPA Computer Science Study Group (CSSG). DARPA-RA-10-76. \$100K. 2011-2012.
- **Michael J. Freedman**. Alfred P. Sloan Foundation, Research Fellowship. \$50K. 2011-2013.
- **Michael J. Freedman** (PI), linked with Philip Levis (Stanford, PI). Meru: Internet-scale Visual Computing. Intel Visual Computing Institute. ~\$85K to Princeton. 2011.
- **Michael J. Freedman** (PI), with 11 other universities (Jonathan Smith, UPenn–Lead PI). NEBULA: A Future Internet That Supports Trustworthy Cloud Computing. NSF Future Internet Architecture (FIA #1040708). \$503K to Princeton, total of \$7.455M. 2010-2013.
- Larry Peterson (PI), **Michael J. Freedman**, Vivek Pai, and Jennifer Rexford. Development of a Virtual Cloud Computing Infrastructure. NSF Major Research Instrumentation (MRI #1040123). \$2.94M.
- Szymon Rusionkiewicz, Adam Finkelstein, **Michael J. Freedman**, and Tom Funkhouser. Intel Visual Computing Institute, seed funding. \$40K. 2010.
- **Michael J. Freedman**. Towards Scalable Datacenter Services with Strong Robustness Guarantees. NSF CSR CAREER (#0953197). \$529K. 2009-2014.

- Margaret Martonosi, Jennifer Rexford, **Michael J. Freedman**, Mung Chiang. Adaptive, Energy-Aware Resource Allocation Across Multiple Tenants in Multiple Data Centers. Google Research Award. \$100K. 2009.
- **Michael J. Freedman** (PI), Scott Karlin, Larry Peterson, Jennifer Rexford, with 6 other universities and Stanford University (Nick McKeown–Lead PI). Campus Trials of Enterprise GENI. NSF via the GENI Product Office (BBN). \$200K to Princeton. 2009–2011.
- **Michael J. Freedman** (PI) and Jennifer Rexford. A SCAFFOLD for GENI-based Distributed Services. NSF via the GENI Product Office (BBN). \$432K. 2009–2012.
- **Michael J. Freedman**. A SCAFFOLD for Service-Centric Networking. Cisco University Research Program Fund. \$100K. 2009.
- **Michael J. Freedman** (PI), Jen Rexford. A SCAFFOLD for Service-Centric Networking. NSF NeTS Medium (#0904729). \$750K. 2009–2013.
- **Michael J. Freedman** (Lead PI), Ramesh Johari (Stanford), Srinivas Shakkotai (Texas A&M). Designing a Content-Aware Internet Ecosystem. NSF NeTS Medium (#0904860). \$340K to Princeton, total of \$896K. 2009–2013.
- **Michael J. Freedman**. Towards a Service-Centric Network Architecture for Fault Tolerance, Migration, and Mobility. ONR Young Investigator Program. \$610K. 2009–2013.
- **Michael J. Freedman**. E. Lawrence Keyes, Jr./Emerson Electric Co. Faculty Advancement Award. \$40K. 2009.
- Mung Chiang, **Michael J. Freedman**, Margaret Martenosi, Jennifer Rexford. Green IT: From the Phone to the Data Center. Princeton Grand Challenges Program. \$200K. 2009–2011.
- **Michael J. Freedman** (PI) and Tom Funkhouser, linked with Philip Levis (PI), Pat Hanrahan, and Vladlen Koltun (Stanford–Lead). A Network Architecture for Federated Virtual/Physical Worlds. NSF NeTS-ANET Medium (#0831374). \$509K to Princeton, total of \$1.459M. 2008–2012.

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Princeton, NJ, February 8, 2012