

# Craig Gutterman

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## Research Interests

My research focuses on improving the performance of future networks and systems by developing machine learning based network systems and data driven network algorithms. In particular, I have worked on tools for traffic prediction, traffic classification, and resource management with applications for multimedia streaming, optical networks, network slicing, wireless multicast, and edge computing. In addition, I assisted in the design and deployment of the NSF PAWR COSMOS testbed.

## Education

### **Columbia University, New York, NY**

Ph.D. Candidate in Electrical Engineering

Sept. 2014 - Present

Advisor: Prof. Gil Zussman

GPA: 4.0

M.S., Electrical Engineering (Tesla Scholar)

Sept. 2012 - Feb. 2014

GPA: 4.14

### **Rutgers University, School of Engineering, New Brunswick, NJ**

B.S., Electrical Engineering, Minors: Economics, Math

Sept. 2008 - May 2012

Concentration: Communications

GPA: 4.0 *Summa Cum Laude*

## Honors & Awards

Top Prize, Enabling Technology for a demo at the NYC Media Lab Summit	2019
IEEE INFOCOM'17 Best Paper Runner-Up	2017
NYC Media Lab Combine Program Grant	2016
<i>awarded \$25,000 funding to evaluate the commercialization potential of research</i>	
Second Place Prize for a demo at the NYC Media Lab Summit	2015
<b>NSF Graduate Research Fellowship</b>	2014
<b>NSF IGERT Fellowship, From Data To Solutions</b>	2014
Columbia University Electrical Engineering M.S. Award of Excellence	2014
<i>granted to less than 5% of the candidates for the M.S. degree for outstanding achievement</i>	
Selected in ACM MC2R as best article from WinTECH 2012 workshop	2013
Columbia University Tesla Scholar	2012
<i>granted to top incoming Electrical Engineering M.S. Students</i>	
<b>Rutgers University John B. Smith Memorial Prize</b>	2012
<i>awarded to highest ranking graduating senior in Dept. of Electrical Eng.</i>	
Rutgers University James J. Slade Scholar	2012
<i>awarded for submitting and presenting honors thesis</i>	
Rutgers University James and Edna Noe Engineering Scholarship	2010 – 2012
<i>awarded for outstanding academic achievement</i>	

## Research Experience

**Columbia University, WiMNet Lab**

**Sept. 2012 - Present**

### **Encrypted Video QoE Prediction**

- Developed a system for real-time quality of experience metric detection for encrypted traffic, Requet. Designed a detection algorithm to identify video and audio chunks from the IP headers of encrypted traffic. Engineered features extracted from the chunk statistics. Trained a random forest to predict QoE metrics, specifically, buffer warning (low buffer, high buffer), video state (buffer increase, buffer decay, steady, stall), and video resolution. Requet outperforms the baseline system based on previous work in accuracy of predicting buffer low warning, video state, and video resolution by 1.12×, 1.53×, and 3.14×, respectively. The design of the system is in collaboration with Nokia Bell Labs. Paper appeared in ACM MMSys'19. Received top prize, "Enabling Technology" for a demo at the NYC Media Lab's Annual Summit'19.

### **Dynamic Optical Networks**

- Developed deep neural network to predict the power dynamics of a 90-channel ROADM multi-hop Reconfigurable Optical Add-Drop Multiplexer (ROADM) network. Designed system to recommend wavelength assignments that contain the power excursion to less than 0.5 dB with a precision of over 99%. The research resulted in papers that were accepted to ECOC'16, ACM SIGCOMM Workshop Big-DAMA'17, ECOC'18, and OSA OFC'18.
- Developed and implemented optical architecture of COSMOS testbed. COSMOS is a city-scale advanced wireless testbed used to support real-world experimentation on next-generation wireless technologies and applications. COSMOS integrates software-defined radios with remote compute, dark fiber optical network, along with a software-define network (SDN) control plane. Designed optical SDN framework that allows COSMOS users to implement experiments with application-driven control of optical and data networking functionalities. Deployed tools and services to configure and monitor the performance of optical paths and topologies of the COSMOS testbed. This work is within the COSMOS project and is in collaboration with WINLAB at Rutgers University and Prof. Dan Kilper's group at the University of Arizona. The research resulted in papers at OSA OFC'19 and IEEE MERIT'19; and a talk at ACM SIGCOMM Workshop OptSys'19.

### **Network Slice Automation**

- Designed a short-term multistep time series prediction model, X-LSTM, of Physical Resource Blocks (PRBs) available to active bearers for a Radio Access Network (RAN) slice broker. X-LSTM outperforms Autoregressive Integrated Moving Average Model (ARIMA) and LSTM neural networks by up to 31%. When used by a slice broker, X-LSTM can reduce costs due to over-provisioning and Service Level Agreement (SLA) violation costs by more than 10% in comparison to LSTM and ARIMA. The design of the system is in collaboration with Nokia Bell Labs. Paper appeared in ACM MobiHoc'19.

### **Adaptive Multicast in WiFi**

- Developed and evaluated rate adaption framework for efficiently sending multicast traffic in WiFi networks. The framework is based on selecting a subset of the nodes to report receiver channel quality. Implemented and evaluated the framework in the ORBIT testbed (400 WiFi nodes). Analyzed large datasets (tens of gigabytes) per experiment using Python and MATLAB. The design of the system was in collaboration with Nokia Bell Labs. The research resulted in papers that were accepted to IEEE ICNP'13, IEEE INFOCOM'16, IEEE/ACM TON'16, and IEEE INFOCOM'17, IEEE TWC'18, IEEE/ACM TON'19. Received 2nd place prize for a demo in the NYC Media Lab Summit. Selected to participate in the NYC Media Lab Combine.

**Rutgers University, WINLAB**

**Sept. 2011 - May 2012**

**Cognitive Radio Communication System Design**

- Designed hardware and performed verification testing for the FPGA of the ORBIT Cognitive Radio kit (CRKIT). Designed the application test bench and communication applications (spectrum sensor and QPSK modulation receiver) for the WINLAB CRKIT framework using MATLAB/Simulink. Developed and implemented a rendezvous algorithm that allows two uncoordinated cognitive radios to establish communication in the presence of interference by opportunistically utilizing available spectrum. The research resulted in a paper presented in ACM WiNTECH'12 and published in ACM Mobile Computing and Communications Review.

**Industry Experience**

**Nokia Bell Labs**

Murray Hill, NJ

**Summer Intern**

May 2018 - Aug. 2018

- Developed a system for real-time quality of experience metric detection for encrypted traffic, Requet. Advised by K. Guo. Paper appeared in ACM MMSys'19.

**Nokia Bell Labs**

Murray Hill, NJ

**Summer Intern**

May 2017 - Aug. 2017

- Designed a short-term multistep time series prediction model, X-LSTM, of Physical Resource Blocks (PRBs) available to active bearers for a Radio Access Network (RAN) slice broker. Advised by E. Grinshpun and S. Sharma. Paper appeared in ACM MobiHoc'19.

**Gotenna**

Brooklyn, NY

**Network Engineer**

Jan. 2014 - Aug. 2014

- Designed proprietary mobile ad-hoc network (MANET) protocol for a new type of wireless device. Developed a protocol to allow for messaging within the user's local area when he/she does not have cell or data service (e.g., hiking, skiing, natural disaster). Built network simulation in MATLAB to analyze network traffic and capacity under different scenarios. Designed scripts to plot experimental results on Google maps for visual analysis and extract data for system analysis.

**Raytheon BBN Technologies**

Cambridge, MA

**Advanced Networking Intern**

June 2013 - Aug. 2013

- Explored the suitability of Android emulators, Virtual Machines, and Linux Containers for ad-hoc network emulation. Analyzed data synchronization overhead for Content Distributed Networks. The problem stems from a topology of a Content Distribution Network (CDN) defined by mobile ad hoc communities of nodes that are bound together and use cooperative storage in each community. Developed and simulated various data synchronization protocols for Content Distribution Network. Compared and contrasted results of alternative protocols to determine optimum use of network resources.

# Publications

## Conference Proceedings

1. **C. Gutterman**, B. Fridman, T. Gilliland, Y. Hu, G. Zussman, “STALLION: Video Adaptation Algorithm for Low-Latency Video Streaming,” in *Proc. ACM MMSys’20*, 2020 (to appear).
2. D. Raychaudhuri, I. Seskar, G. Zussman, T. Korakis, D. Kilper, J. Kolodiejski, M. Sherman, T. Chen, Z. Kostic, X. Gu, H. Krishnaswamy, S. Maheshwari, P. Skrimponis, **C. Gutterman**, “Challenge: COSMOS: A City-Scale Programmable Testbed for Experimentation with Advanced Wireless,” in *Proc. ACM MobiCom’20*, 2020, acceptance rate 17.3% (24/139).
3. S. Zhu, **C. Gutterman**, A. Montiel, J. Yu, M. Ruffini, G. Zussman, and D. Kilper, “Hybrid Machine Learning EDFA Model,” in *Proc. OSA OFC’20*, 2020.
4. J. Yu, **C. Gutterman**, A. Minakhmetov, M. Sherman, T. Chen, S. Zhu, G. Zussman, I. Seskar, and D. Kilper, “Dual Use SDN Controller for Management and Experimentation in a Field Deployed Testbed,” in *Proc. OSA OFC’20*, 2020.
5. A. Minakhmetov, **C. Gutterman**, T. Chen, J. Yu, C. Ware, L. Iannone, D. Kilper, and G. Zussman, “Experiments on Cloud-RAN Wireless Handover using Optical Switching in a Dense Urban Testbed,” in *Proc. OSA OFC’20*, 2020.
6. **C. Gutterman**, E. Grinshpun, S. Sharma, and G. Zussman, “RAN resource usage prediction for a 5G slice broker,” in *Proc. ACM MobiHoc’19*, 2019, acceptance rate 23.7% (31/156).
7. **C. Gutterman**, K. Guo, S. Arora, X. Wang, L. Wu, E. Katz-Bassett, and G. Zussman, “Requet: Real-Time QoE Detection for Encrypted YouTube Traffic,” in *Proc. ACM MMSys’19*, 2019, acceptance rate 40.4% (21/52).
8. J. Yu, T. Chen, **C. Gutterman**, S. Zhu, G. Zussman, I. Seskar, and D. Kilper, “COSMOS: Optical architecture and prototyping,” in *Proc. OSA OFC’19 (invited)*, 2019.
9. S. Zhu, **C. Gutterman**, W. Mo, Y. Li, G. Zussman, and D. Kilper, “Machine learning based prediction of erbium-doped fiber WDM line amplifier gain spectra,” in *Proc. ECOC’18*, 2018.
10. W. Mo, **C. Gutterman**, Y. Li, G. Zussman, and D. Kilper, “Deep neural network based dynamic resource reallocation of BBU pools in 5G C-RAN ROADM networks,” in *Proc. OSA OFC’18*, 2018.
11. Y. Bejerano, C. Raman, C. Yu, V. Gupta, **C. Gutterman**, T. Young, H. Infante, Y. Abdelmalek, G. Zussman, “DyMo: Dynamic Monitoring of Large Scale LTE-Multicast Systems,” in *Proc. IEEE INFOCOM’17*, 2017, acceptance rate 20.9% (292/1395).  
**Best Paper Runner-Up**
12. Y. Huang, W. Samoud, **C. Gutterman**, C. Ware, M. Lourdiane, G. Zussman, P. Samadi, K. Bergman, “A Machine Learning Approach for Dynamic Optical Channel Add/Drop Strategies that Minimize EDFA Power Excursions,” in *Proc. ECOC’16*, 2016.
13. Y. Bejerano, V. Gupta, **C. Gutterman**, and G. Zussman, “AMuSe: Adaptive Multicast Services to very large groups Project overview”, in *Proc. ICCCN’16 (invited)*, 2016.
14. V. Gupta, **C. Gutterman**, Y. Bejerano, and G. Zussman, “Experimental evaluation of large scale WiFi multicast rate control,” in *Proc. IEEE INFOCOM’16*, 2016, acceptance rate 18.2% (300/1644).

15. Y. Bejerano, J. Ferragut, K. Guo, V. Gupta, **C. Gutterman**, T. Nandagopal, G. Zussman, “Scalable WiFi Multicast Services for Very Large Groups,” in *Proc. IEEE ICNP’13*, 2013, acceptance rate 18.3% (46/252).

## Workshop Proceedings

1. **C. Gutterman**, A. Minakhmetov, J. Yu, M. Sherman, T. Chen, S. Zhu, I. Seskar, D. Raychaudhuri, D. Kilper, and G. Zussman, “Programmable Optical x-Haul Network in the COSMOS Testbed,” in *Proc. IEEE ICNP’19 Workshop on Midscale Education and Research and Research Infrastructure and Tools (MERIT’19)*, 2019.
2. **C. Gutterman**, A. Minakhmetov, M. Sherman, J. Yu, T. Chen, S. Zhu, G. Zussman, I. Seskar, D. Raychaudhuri, and D. Kilper, “COSMOS: Optical Architecture and Prototyping,” in *Proc. ACM SIGCOMM’19 Workshop on Optical Systems Design (Oplsys’19)*, 2019.
3. **C. Gutterman**, W. Mo, S. Zhu, Y. Li, D. Kilper, G. Zussman, “Neural Network Based Wavelength Assignment in Optical Switching,” in *Proc. ACM SIGCOMM’17 Workshop on Big Data Analytics and Machine Learning for Data Communication Networks (Big-DAMA’17)*, Aug. 2017.
4. Y. Bejerano, J. Ferragut, K. Guo, V. Gupta, **C. Gutterman**, T. Nandagopal, and G. Zussman, “Experimental evaluation of a scalable WiFi multicast scheme in the ORBIT testbed,” in *Proc. 3rd GENI Research and Educational Experiment Workshop (GREE’14)*, Mar. 2014.
5. K. Le, P. Maddala, **C. Gutterman**, K. Soska, A. Dutta, D. Saha, P. Wolniansky, D. Grunwald, and I. Seskar, “Cognitive Radio Kit Framework: Experimental Platform for Dynamic Spectrum Research,” in *Proc. 7th ACM International Workshop on Wireless Network Testbeds, Experimental Evaluation, and Characterization (ACM WiNTECH’12)*, Istanbul, Turkey, Aug. 2012.

## Journal Publications

1. **C. Gutterman**, K. Guo, S. Arora, T. Gilliland, X. Wang, L. Wu, E. Katz-Bassett, and G. Zussman, “Requet: Real-Time QoE Detection for Encrypted YouTube Traffic,” in *ACM Transactions. On Multimedia Computing, Communications, and Applications*, 2020 (to appear).
2. Y. Bejerano, C. Raman, C. Yu, V. Gupta, **C. Gutterman**, T. Young, H. Infante, Y. Abdelmalek, G. Zussman, “DyMo: Dynamic Monitoring of large scale LTE-multicast systems,” in *IEEE/ACM Transactions on Networking*, vol. 27, no. 1, pp 258-271, Feb. 2019.  
**Fast-tracked from IEEE INFOCOM’17**
3. W. Mo, **C. Gutterman**, Y. Li, S. Zhu, G. Zussman, D. Kilper, “Deep Neural Network Based Wavelength Selection and Switching in ROADMs Systems”, in *Journal of Optical Communications and Networking*, vol. 10, no. 10, pp. D1–D11, Oct. 2018.
4. V. Gupta, **C. Gutterman**, Y. Bejerano, and G. Zussman, “Experimental Evaluation of Large Scale WiFi Multicast Rate Control,” in *IEEE Transactions in Wireless Communications*, vol. 17, no. 4, pp. 2319–2332, Apr. 2018.
5. Y. Huang, **C. Gutterman**, P. Samadi, P. Cho, W. Samoud, C. Ware, M. Lourdiane, G. Zussman, K. Bergman, “Dynamic mitigation of EDFA power excursions with machine learning,” in *Optics Express*, vol. 25, no. 3, pp. 2245-2258, Feb. 2017.
6. V. Gupta, Y. Bejerano, **C. Gutterman**, J. Ferragut, K. Guo, T. Nandagopal, G. Zussman, “Light-weight feedback mechanism for WiFi multicast to very large groups – experimental evaluation,” in *IEEE/ACM Transactions on Networking*, vol. 24, no. 6, pp. 3826-3840, Dec. 2016.

7. K. Le, P. Maddala, **C. Gutterman**, K. Soska, A. Dutta, D. Saha, P. Wolniansky, D. Grunwald, and I. Seskar, "Cognitive Radio Kit Framework: Experimental Platform for Dynamic Spectrum Research," *ACM Mobile Computing and Communications Review (ACM MC2R)* Vol. 17 No. 1 pp. 30-39, Jan. 2013.

Selected as best article from WinTECH 2012 workshop

## Conference Demonstrations

1. **C. Gutterman**, A. Minakhmetov, M. Sherman, J. Yu, T. Chen, S. Zhu, G. Zussman, I. Seskar, D. Raychaudhuri, and D. Kilper, "COSMOS: Optical Architecture and Prototyping," in *Proc. ACM SIGCOMM'19 Workshop on Optical Systems Design (OptSys'19)*, 2019.
2. V. Gupta, L. Xu, B. Wu, S. Petridis, **C. Gutterman**, Y. Bejerano, and G. Zussman, "Evaluating Video Delivery over Wireless Multicast," *Demo in Proc IEEE INFOCOM'17*, 2017.
3. V. Gupta, R. Norwitz, S. Petridis, **C. Gutterman**, G. Zussman, and Y. Bejerano, "AMuSe: Large-scale WiFi Video Distribution - Experimentation on the ORBIT Testbed," *Demo in Proc IEEE INFOCOM'16*, 2016.
4. V. Gupta, R. Norwitz, S. Petridis, **C. Gutterman**, G. Zussman, and Y. Bejerano, "WiFi multicast to very large groups – experimentation on the ORBIT testbed," in *Proc. IEEE LCN'15*, 2015.

## Talks, Demos and Additional Presentations

1. "Real-Time QoE Detection for Encrypted Video Traffic," AT&T Graduate Student Symposium, 2019.
2. "Requet: Real-Time QoE Detection for Encrypted YouTube Traffic," NYC Media Lab's Annual Summit, 2019. (demo)
3. "Optical Path Management in the ORBIT/COSMOS Testbed," COSMOS Experimenters Workshop, Rutgers University, NJ, May 2019. (tutorial and demo)
4. "Real-Time QoE Detection for Encrypted YouTube Traffic" Columbia University Data Science Day, New York, NY, Apr. 2019. (demo)
5. "Power Excursion Mitigation in Optical Networks via Machine Learning – Experimental Evaluation" Columbia University Data Science Institute, New York, NY, March 2017. (demo)
6. "Interactive Adaptive Video Streaming on Smartphones", NYC Media Lab's Annual Summit, New York, NY, Sept. 2016. (demo)
7. "AMuSe – Content Delivery in Crowded Areas Through WiFi Multicast", NYC Media Lab 's Combine Demo Day, New York, NY, April 2016. (talk)
8. "Large Scale Video Delivery over WiFi", Columbia University Data Science Day, New York, NY, March 2016. (demo)
9. "WiFi Multicast to Very Large Groups – Experimentation on the ORBIT Testbed", GENI NICE, San Francisco, CA, Nov. 2015. (demo)
10. "AMuSe – Content Delivery in Crowded Areas Through WiFi Multicast", Razorfish Innovation Summit, New York, NY, Sept. 2015. (invited demo)
11. "AMuSe – Content Delivery in Crowded Areas Through WiFi Multicast", NYC Media Lab's Annual Summit, New York, NY, Sept. 2015. (demo)

2nd place prize

## Teaching Experience

Teaching Assistant, 5G Programmable Networks, Columbia University  
 Teaching Assistant, Computer Networks, Columbia University  
 Teaching Assistant, Computer Networks, Columbia University

Spring 2018  
 Spring 2017  
 Summer 2016

Teaching Assistant, Computer Networks, Columbia University  
Teaching Assistant, Networking Laboratory, Columbia University

Summer 2015  
Fall 2013

## Mentoring and Advising

### Master Students

Guanxuan Li (Spring 2019-Present)	
Josh Rutta (Spring 2019-Summer 2019)	Amazon
Siao-Ting Wang (Fall 2018)	Amazon
Ido Michael (Fall 2017)	Amazon

### Undergraduate Students

Yusheng Hu (Summer 2019- Present)	
Trey Gilliland (Summer 2019 – Present)	
Gharvhel Carre (Fall 2018 - Spring 2019)	Amazon
Jenny Li (Fall 2018 - Spring 2019)	Columbia University Undergraduate
Sarthak Arora (Fall 2017 – Spring 2019)	Google
Andy Xu (Summer 2016 - Spring 2019)	Facebook
Bohan Wu (Summer 2016)	Columbia University Graduate Student
Raphael Norwitz (Summer 2015)	Nutanix
Savvas Petridis (Summer 2015 - Fall 2015)	Columbia University Ph.D. Candidate

### High School Students

Rodda John (Summer 2016- Spring 2019)	Columbia University Undergraduate
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## Relevant Coursework

Information Theory, Probability and Random Processes, Stochastic Signals, Communication System Design, Wireless Communication Systems, Digital Signal Processing, Computer and Communication Networks, Wireless and Mobile Networks, Algebraic Coding Theory, MIMO Wireless Communications, Analysis of Algorithms I, Detection and Estimation Theory, Convex Optimization, Stochastic Models, Machine Learning, Optimization II, Bayesian Modeling For Machine Learning

## Technical Skills

*Programming Languages:* Python, MATLAB, SQL, C/C++, TensorFlow, Keras  
*Operating Systems:* Linux, Mac OS, Windows