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NYU WIRELESS is the News

NYU WIRELESS is a vibrant academic research center pushing the boundaries of wireless communications, sensing, networking, and devices.

Centered at the NYU Tandon School of Engineering and involving leaders from industry, faculty, and students throughout the entire NYU community, NYU WIRELESS offers its Industrial Affiliate members, students, and faculty members a world-class research environment that is creating fundamental knowledge, theories, and techniques for future mass-deployable wireless devices in a wide range of applications and markets.

Every January, NYU WIRELESS hosts an annual Open House for all of its students and Industrial Affiliate Members and hosts a major invitation-only wireless summit every April, in cooperation with Nokia Bell Laboratories, for the center’s Industrial Affiliates and thought leaders throughout the global telecommunications industry.

NYU WIRELESS, info@nyuwireless.com

Leadership: Founding Director Ted Rappaport and Associate Directors Sundeep Rangan, Thomas L. Marzetta, John-Ross Rizzo, and Dennis Shasha manage NYU WIRELESS across Brooklyn and Manhattan campuses of NYU. Prof. Rappaport has powered the 5G millimeter wave era and is a leading educator in the wireless arena, having authored many books and started three major academic wireless research centers. Prof. Rangan is an Electrical Engineering professor at NYU Tandon and was a co-founder of Flarion Technologies, which developed Flash OFDM, one of the first cellular OFDM data systems. Prof. Marzetta originated the concept of Massive MIMO and continues to sustain contributions to the development and promotion of Massive MIMO. Prof. J. R. Rizzo is an assistant professor in the Departments of Rehabilitation Medicine and Neurology at NYU Langone Health. His research is focused on wearable technology and blindness and visual impairment. Prof. Shasha of Courant’s Computer Science Department is widely known for his expertise in data-intensive algorithms, streaming data, and is a highly acclaimed inventor of mathematical puzzles.

The Industrial Affiliates Program: NYU WIRELESS invites corporate supporters to join our Industrial Affiliates program. The NYU WIRELESS Industrial Affiliates program offers a mutually beneficial relationship between NYU WIRELESS researchers, students, and facilities, and leading industry partners, while fostering innovative research. NYU WIRELESS would like to thank our Industrial Affiliate Partners and NSF for their continued support. Learn more about our Industrial Affiliate program by visiting nyuwireless.com/industrial-affiliates.

About the cover: Parisa Hassanzadeh, a student of NYU WIRELESS, graduated with her Ph.D. and is shown at the NYU All-University Commencement in Yankee Stadium on May 22, 2019. Parisa had the highest GPA among all graduating students at the NYU Tandon School of Engineering, and served as the Graduate Class Representative. She also received the 2019 David Goodman Research Award, given to the student in the Electrical and Computer Engineering (ECE) Department who made the most significant research contribution among all ECE graduate students in the past year. The research award is named for the beloved wireless pioneer and current NYU WIRELESS Professor Emeritus, who still frequents campus regularly. Parisa graduated under the advisement of Professor Elza Erkip and is slated to join the Artificial Intelligence Research Group at JP Morgan.

“6G and Beyond” Explored in IEEE Access Journal

Following the groundbreaking paper published by NYU WIRELESS Founder and Director Ted Rappaport and colleagues in 2013 titled, “Millimeter Wave Mobile Communications for 5G Cellular: It Will Work!,” NYU WIRELESS has now published a cutting-edge successor that sets a vision for 6G: “Wireless Communications and Applications Above 100 GHz: Opportunities and Challenges for 6G and Beyond.” Published by IEEE Access on June 6, 2019, and available for free download, this invited paper explores the potential of the sixth generation (6G) of wireless networks and beyond. In recognition of its importance, it was selected as article of the week by IEEE Access on August 23, 2019. In addition to Ted, co-authors of the paper include Associate Professor Arjuna Madanayake of Florida International University; Assistant Professor Soumyajit Mandal of Case School of Engineering, Case Western Reserve; Assistant Professor Ahmed Alkhateeb and Assistant Professor Georgios C. Trichopoulos of Arizona State University; and NYU WIRELESS students Yunchou Xing, Ojas Kanhere, and Shihao Ju.

The paper points out that 5G wireless networks are currently in commercial development, and attention must now turn to the needs of the next generation of applications, including virtual/augmented reality (VR/AR), autonomous driving, and the use of the smart

phone as a multifaceted sensor and data collector for the world around us. The paper evaluates opportunities, challenges, and methods of creating systems at frequencies above 100 GHz, which Ted and his co-authors postulate

The paper makes a compelling case for computing capabilities that will grow to enable wireless cognition, where wireless remote control of robotic platforms will be done using information rates that support processing powers close to those of the human brain.

will be part of 6G in the years 2025 to 2030. The work describes fundamental challenges and promising approaches to densely packed antenna arrays, analysis techniques for determining tradeoffs for power consumption and link budgets, new position location and imaging approaches, and signal processing methods for phased arrays that are more efficient and compact. The work highlights the potential applications of THz wireless that will be used by automated machinery, spectroscopy, autonomous cars, and new human interfaces. The paper makes a compelling case for computing capabilities that will grow to enable wireless cognition, where wireless remote control of robotic platforms will be done using information rates that support processing powers close to those of the human brain. 

This exciting paper, which has rapidly become one of IEEE’s most popular, may be found online at ieeexplore.ieee.org/document/8732419.

SPECIAL SECTION ON MILLIMETER-WAVE AND TERAHERTZ PROPAGATION, CHANNEL MODELING AND APPLICATIONS

IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

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Digital Object Identifier 10.1109/ACCESS.2019.2921522

• INVITED PAPER

Wireless Communications and Applications Above 100 GHz: Opportunities and Challenges for 6G and Beyond

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OJAS KANHERE¹, **SHIHAO JU¹**, **ARJUNA MADANAYAKE²**, (Member, IEEE),
SOUMYAJIT MANDAL³, (Senior Member, IEEE), **AHMED ALKHATEEB⁴**,
AND GEORGIOS C. TRICHOPOULOS⁴, (Member, IEEE)

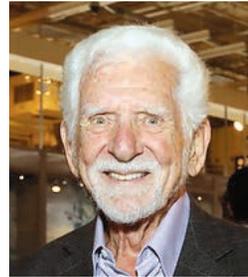
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It's for You!

Cellular Pioneer Marty Cooper Donates Historic Cell Phone Replica

The NYU WIRELESS museum was greatly enhanced recently by the donation of a life-like replica of Motorola's very first cell phone, the DynaTAC, by its creator, Marty Cooper. The DynaTAC was the first commercially available cell phone in the world. It was manufactured by Motorola from 1983 to 1994, took 10 hours to charge, offered 30 minutes of talk time,



Marty Cooper

and was priced at \$3,995 in 1983 (which would be \$10,291 in 2019)! Marty is credited with the invention of the cell phone in 1973 and leading the team that brought it to the marketplace. In

recognition of the global impact that Marty has had on society, he was presented with the first Pioneer Award at the 2018 Brooklyn 5G Summit. We are grateful to Marty for this wonderful gift to NYU WIRELESS! 

FCC Chairman Ajit Pai Visits Paley Center

The Paley Center for Media, first known as the Museum of Broadcasting and then the Museum of Television & Radio prior to its current designation, is a national treasure dedicated to preserving and fostering dialogue within the media. Since its inception by founder William S. Paley in 1975, it has hosted an open dialogue with every sitting Federal Communications Commission (FCC) Chairman. On June 20, 2019, The Paley Center hosted FCC Chairman Ajit Pai for a Paley Dialogue, moderated by NYU WIRELESS founder and Director Ted Rappaport. For nearly an hour, Pai and Rappaport had a wide-ranging discussion, which included the approach that Pai takes in working with the Commission's staff of nearly 2,000 to regulate all of the media and telecommunications policy in America. Pai noted that there are a vast number of laws

and regulations that have not kept up with the pace of technology, and how he views his role to help protect Americans while encouraging growth and technology adoption that can benefit the country. Chairman Pai discussed 5G deployment and the importance it has for America, his views and rationale for the FCC's stance on net neutrality, his desire to close the digital divide, and the effects that social media is having on society. He pointed out the power of new internet-based companies that have access to so much of our personal information but do not offer transparency regarding how they use and monetize that information. Rappaport asked the Chairman if over-the-top (OTT) providers are investing enough to ensure the "pipes and infrastructure" in our country are able to keep up with global competition,

while ensuring America has access to information and the ability to innovate into the coming decades.

The Paley Center for Media is part of the Paley Media Council, which is an invitation-only organization that provides a forum for industry leaders to explore the impact of media and technology on society. More information about the Center can be found at paleycenter.org/ 



Ted Rappaport and FCC Chair Ajit Pai

NYU WIRELESS Founder Ted Rappaport Selected to Wireless Hall of Fame

NYU Wireless Founding Director Ted Rappaport will be inducted into the Wireless History Foundation Wireless Hall of Fame at the Foundation's Awards Dinner on October 23, 2019, in Los Angeles. One of the wireless industry's highest honors, the Wireless History Foundation recognized Ted as a "groundbreaking academic and entrepreneur whose work has paved the way for modern wireless communication systems." Also inducted into the Hall of Fame will be Android founders Rich Miner, Andy Rubin, Nick Sears, and Chris White, as well as the posthumous award to Lawrence D. Garvey, a pioneer in two-way voice systems and paging.

Ted's groundbreaking research, conducted at NYU WIRELESS, and previously at two other large academic wireless research centers that he also founded (at The University of Texas and Virginia Tech), is widely recognized as laying the fundamental groundwork for modern wireless communications systems. His work helped develop the world's first Wi-Fi networks, the first digital cellular standards for the US, and today's 5G technologies. Ted's work continues to blaze a trail for future wireless innovations, as

exemplified in his latest comprehensive research overview, "Wireless Communications and Applications Above 100 GHz: Opportunities and Challenges for 6G and Beyond." This work highlights the technical challenges and opportunities for the coming decades, particularly in the terahertz (THz) electromagnetic frequency bands (see page 1 for more information about this paper).

In being named to the Wireless Hall of Fame, Rappaport's body of work was recognized for influencing the education and career paths of thousands of engineers and educators within the three academic research centers that he has founded, and countless thousands of others who have learned from his many highly cited textbooks in the field of wireless communications that have been translated into many languages. During his career, he launched two successful high-tech companies and advised many others, and has over 100 patents to his name. Ted's recent entrance into the Wireless Hall of Fame is testimony to his leadership, ingenuity, and visionary thinking. We as a community are reaping the rewards of the technological advances to which he has contributed, often as a pioneer! 🍷



Ted Rappaport

ComSenTer Announces First Doctoral Graduate

The consortium of universities, industrial partners, and government agencies that composes ComSenTer (Communications Sensing Terahertz) has announced its first doctoral student graduate, Menglei Zhang from NYU WIRELESS. ComSenTer is part of the DARPA and corporate-funded JUMP—Joint University Microelectronics Program—and is designed to develop new generations of wireless communications systems that provide extremely high aggregate data transmission capacities. In addition to NYU WIRELESS, participants in ComSenTer are UC Berkeley, UC San Diego, Cornell University, MIT, Stanford University, UT Dallas, USC, and Columbia University. The consortium is led by UC Santa Barbara.

Menglei's thesis, "Will TCP work in Low Latency Networks?," studied congestion control protocols in the low latency 5G network, which will assist operators in improving network configurations upon deployment of low latency links. Menglei was a student of NYU WIRELESS' Sundeep Rangan, and he was offered a position with Intel after graduation. Intel is a former member of NYU WIRELESS. More information can be found at the new web site, Comsenter.engr.ucsb.edu. 🍷



(l. to r.) Associate Professor Yong Liu; NYU WIRELESS Associate Director Sundeep Rangan; Menglei Zhang; Postdoctoral Research Scientist Marco Mezzavilla; and Professor Shivendra Panwar

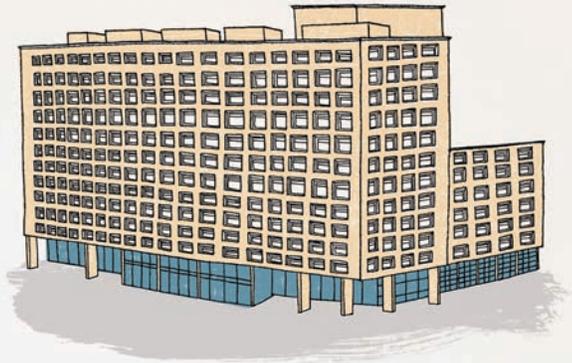


A New Home for NYU WIRELESS

People react differently to change—some people embrace it, while some resist it, as they are used to old patterns and comfortable situations. But often unexpected growth and synergies arise from change—which are the goals of the new home of NYU WIRELESS at 370 Jay Street in Brooklyn. A major new NYU hub for engineering, applied science, urban science, digital technology, and digital media arts, the 370 Jay Street building is a remarkable addition to the NYU campus.

The new building, one of Brooklyn's largest, has over a half-million square feet and was originally opened in 1951 as the central headquarters of the New York City Board of Transportation, which is now the Metropolitan Transit Authority (MTA). In 1990, the Transit Authority relocated to new facilities, and the building was unoccupied for years. NYU took part in an applied science competition in 2012, launched by Mayor Michael Bloomberg to attract top universities to New York City, and submitted a plan for a new education and research center featuring engineering. While Cornell and Technion won the first-place prize, major land on Roosevelt Island, NYU was awarded the second-place prize, a 99-year lease at 370 Jay Street for \$1/year. The design plans were developed by the architectural firm Mitchell Giurgola, and the amazing project was recognized with a SARA New York Design Award of Honor in 2019.

The new location at 370 Jay Street will allow NYU WIRELESS researchers to stay connected with collaborators across the entire NYU campus who are now also housed within the building in Brooklyn, and our students, faculty, Industrial Affiliate Members, and guests now have a great deal more inviting, open, and visible labs; state-of-the-art conference rooms; and much greater space and access to cross-disciplinary investigators on other floors. The roof-top access available to NYU WIRELESS provides a unique and powerful research tool that enables NYU WIRELESS and



its Industrial Affiliates to use an extremely valuable asset for fixed and mobile wireless communications research for decades to come, with visibility to much of Brooklyn and into Manhattan, as well as across the street to the original Brooklyn Poly campus.

A new NYU amateur radio station room will also be installed on the 9th floor of 370 Jay Street, on the same floor as NYU WIRELESS, with Prof. Ted Rappaport, N9NB, serving as the faculty advisor of the new campus-wide station.

One of the unique features of 370 Jay Street is its roof-based microturbine, which is a component of a co-generation plant that recovers some of the waste heat that is produced from power use. The plant was installed as part of NYU's efforts to reduce its carbon footprint. As part of its mission to make 370 Jay Street an exciting and valuable part of its Brooklyn neighborhood, NYU is installing new retail stores and exhibit spaces on the ground floor.

NYU WIRELESS Director Ted Rappaport commented, "We look forward to welcoming our students, Industrial Affiliate member companies, and guests into our exciting new space. We are so grateful to the administration of NYU Tandon, and leaders throughout NYU, as well as the design teams, who have transformed the 370 Jay MTA building into this incredible engineering, media, and digital arts hub. While many board members have seen the building under construction, we are very excited to host our open house and recruiting day in January 2020, where all of our Industrial Affiliate companies will see first-hand how amazing this space is." ❧

Illustration: Charlotte Farmer

IEEE Honors Work by NYU WIRELESS Researchers

Two NYU WIRELESS faculty members won multi-year 2019 Best Paper Awards from the Institute of Electrical and Electronics Engineers Communications Society (IEEE ComSoc)—a prestigious and unusual double accolade for faculty members from the same university, and a third NYU WIRELESS faculty member has received an IEEE Field Award.

Distinguished Industry Professor Thomas L. Marzetta, the newest faculty member within NYU WIRELESS, and the person widely credited as the originator of Massive MIMO antenna

technology. Elza's research uses tools from information theory, communication theory, and applied probability and statistics to understand the theoretical foundations of wireless networks and social networks. Tom looks for breakthroughs in the wireless physical layer through a unification of electromagnetic theory and communication theory.

In his prize-winning paper, "Massive MIMO: Ten Myths and One Critical Question," Tom and co-authors tackle some of the most common misconceptions about MIMO (multi-input, multi-output) and explore key issues that may impact widespread adoption of this technology. This is Tom's second paper to win the Fred W. Ellersick prize.

Elza's IEEE ComSoc award-winning paper addresses the potential of energy harvesting for wireless communications—the process of capturing and storing ambient energy from solar, wind, water, or other external sources to power electrical devices. "Energy Harvesting Wireless Communications: A Review of Recent Advances" details progress in the area of communication systems powered by energy harvesting and reviews various models for designing wireless networks composed of energy harvesting nodes, including self-sustaining wireless networks.

The winners were announced at the IEEE International Conference on Communications in Shanghai, China, in May 2019.

Rounding out the accolades for NYU WIRELESS, founder and Director Ted Rappaport was named the recipient of the 2020 IEEE Eric E. Sumner Field Award for contributions in wireless communications. He shall be presented the Sumner medal at the 2019 IEEE Global Communications Conference in Hawaii this December.

NYU Tandon School of Engineering Dean Jelena Kovačević congratulated the professors, noting that "Professors Marzetta and Erkip are celebrated researchers and educators, and these awards are further proof of the power of their work to inspire and challenge both their peers and students alike. Wireless communications are



Tom Marzetta and Elza Erkip

technology, is the winner of the 2019 Fred W. Ellersick Prize, which recognizes one outstanding paper published in an IEEE ComSoc magazine over a three-year period. Communications and networking pioneer and Institute Professor Elza Erkip received the 2019 Best Tutorial Paper Award, which honors an exceptional tutorial published by IEEE ComSoc in the previous five years. Elza is a founding member of NYU WIRELESS, and Tom is an Associate Director. Additionally, Ted Rappaport, the founder of NYU WIRELESS, has been named as recipient of the 2020 Eric E. Sumner award from IEEE.

Tom and Elza are widely recognized researchers whose contributions are transforming the fast-changing field of wireless communications. Both pursue research with a long-term point of view, aiming to elucidate what is fundamentally possible rather than what is merely

shaping the future like few other technologies, and we are proud to see our faculty honored for their contributions at the forefront of the field.” Dean Kovačević also commented, “Ted Rappaport has been a linchpin in making NYU a world leader in the field of wireless communications, as well as an educator who has inspired and nurtured the next generation of innovators.”

Tom, who spent two decades at Bell Labs before joining NYU Tandon in 2017, is best known for originating Massive MIMO, a system that utilizes numerous arrays of small, individually controlled, low-power antennas to direct streams of information to many users simultaneously with far greater spectral efficiency than current cellular networks. MIMO is considered an essential technology for future wireless networks, as researchers and mobile communications providers work to keep pace with the growing global demand for bandwidth.

Elza has garnered multiple IEEE ComSoc honors, including the Stephen O. Rice Paper Prize (2004), the Award for Advances in Communication (2013), the Women in Communications Engineering Award (2016), and the Communication Theory Technical Committee 2018 Technical Achievement Award. A former president of the IEEE Information Theory Society, she is an oft-cited expert in the fields of wireless networking, communication theory, and information theory.

In the early years of her nearly 20-year tenure at NYU Tandon, she conducted research that would become the foundation for cooperative wireless networking, which aims to mitigate interference and bolster unreliable links between mobile devices and wireless base stations by allowing devices to assist each other in information transmission. This seminal work has impacted industry standardization and inspired new wireless devices.

Rappaport, who founded previous wireless centers at Virginia Tech and The University of Texas before launching NYU WIRELESS in 2012, has provided many pioneering breakthroughs and seminal contributions for the modern wireless era. He noted, “Having colleagues like Elza and Tom is inspiring and provides our center with incredible research capabilities and forward-looking insights that help our students, colleagues, and Industrial Affiliate Members.”

NYU WIRELESS Takes to the Sky!

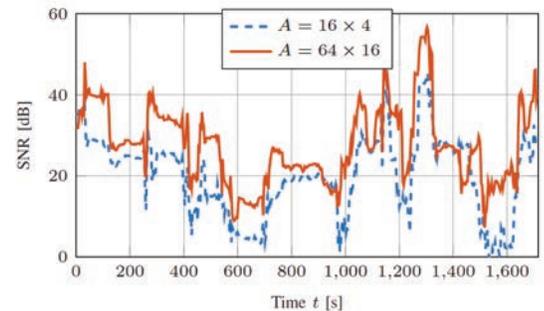
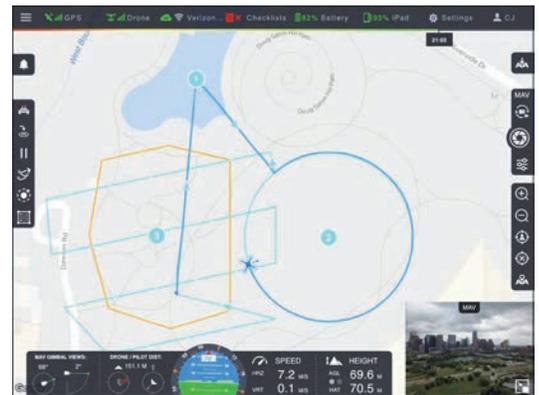
New Millimeter Wave UAV Communication Research

NYU WIRELESS researchers recently presented an important paper about a simulation study designed to assess the feasibility of public safety unmanned aerial vehicle (UAV) connectivity through a 5G link at 28 GHz. The paper, “Millimeter Wave Remote UAV Control and Communications for Public Safety Scenarios,” was presented at the IEEE SECON Conference held June 10-13, 2019, in Boston, and was authored by William Xia, Michele Polese, Marco Mezzavilla, Giuseppe Loiano, Sundeep Rangan, and Michele Zorzi. UAV communication is one of the key emerging

use cases for mmWave and sub-THz communications. The mmWave and sub-THz bands enable high bandwidth and ultra-low latency communication links, offering the potential for high definition streaming video as well as fast UAV remote control. The work focused on UAVs in public safety scenarios. In these settings, the mmWave and sub-THz links can be used to provide wireless connectivity to first responders in a disaster scenario where the cellular infrastructure is unavailable or not operational.

A key challenge is maintaining reliable aerial communication due to the need to support high-speed beam tracking and overcome blockage. The work is supported by a NIST grant on mmWave public safety, the Austin Fire Department, the company Drone Sense which provided real traces from emergency scenarios and the DCIST CRA Distributed and Collaborative Intelligent Systems and Technology Collaborative Research Alliance.

Below, top: Example drone trace provided by the company Drone Sense, used for simulating UAV communications. Below, bottom: Estimated SNR with beamforming for different arrays at 28 GHz. See Xia et al., “Millimeter Wave Remote UAV Control and Communications for Public Safety Scenarios,” IEEE SECON.





Brooklyn 5G Summit (B5GS) 2019 Highlights

The sixth Brooklyn 5G Summit was held on April 23-26, 2019, on the NYU Tandon School of Engineering campus. An invitation-only event, the Summit has become more impactful and exciting each time it is held. This year's B5GS was led by Nokia's Chief Executive Officer, Rajeev Suri, who explained how the world of applications and features will drive 5G into new markets, such as industrial automation and autonomous vehicles. Keynotes by the Chief Technology Officers of two of America's largest carriers, AT&T and Sprint, explained their real-world, on-the-ground experiences of their first 5G implementations in the United States, and FCC Commissioner Michael O'Rielly discussed the urgent need for mid-band spectrum to facilitate 5G rollouts. Captivating keynotes

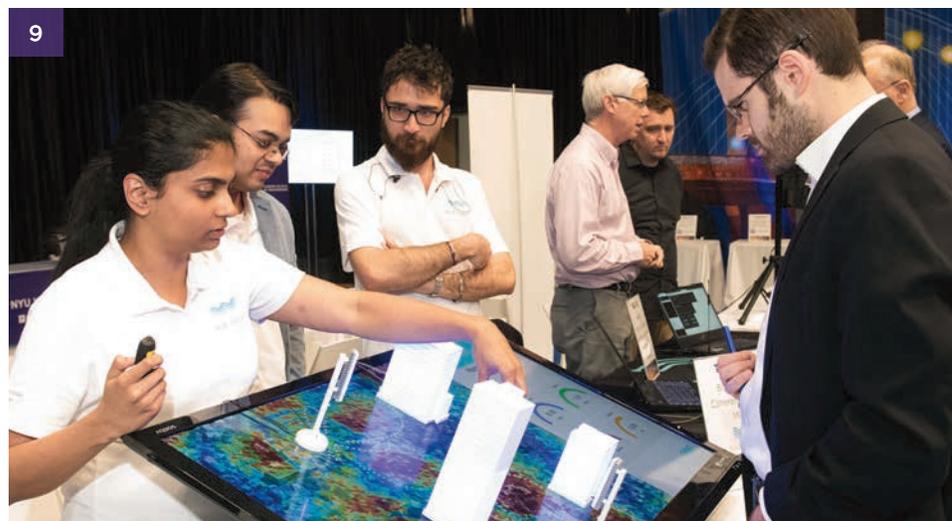
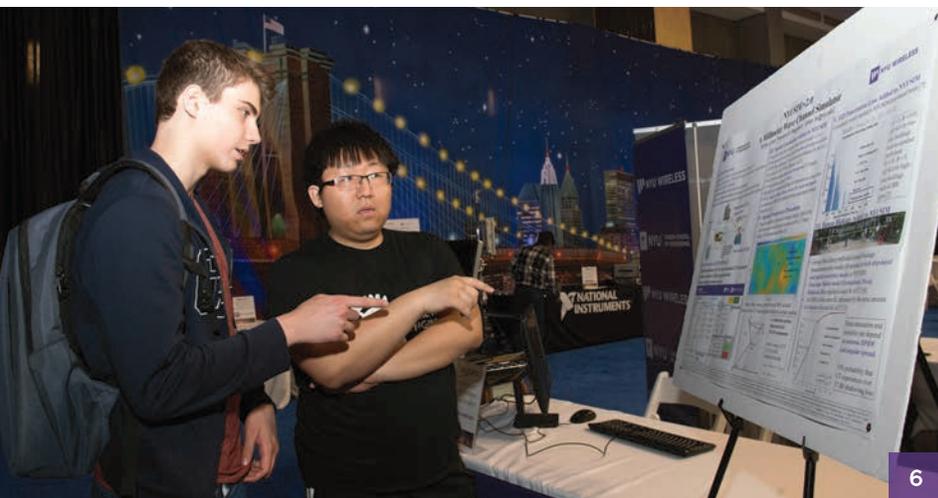
by academics and leading industrial experts explored artificial intelligence and the future of 6G, and we had over 20 new products and prototypes in the exhibition hall.

A highlight of the 2019 Brooklyn 5G Summit was the VIP dinner held at the New York Academy of Sciences, featuring an entertaining fire-side chat with Dr. Irwin Jacobs, the co-founder and former Chairman of Qualcomm. Dr. Jacobs led the commercialization of CDMA (Code Division Multiple Access) digital wireless technology, and told of the life experiences that led him to the West Coast and to form Qualcomm.

The B5GS was developed by NYU WIRELESS Founder and Director Ted Rappaport and Nokia Fellow Amitava Ghosh in 2013, and together they have planned and executed the program with the support of NYU WIRELESS Industrial Affiliate member Nokia every year since 2014. The topics discussed at the conference always look to the future of the wireless industry, and have helped propel the commercialization of 5G, and now are addressing the evolution of beyond 5G leading to 6G. The B5GS is put on for the NYU WIRELESS Industrial Affiliate member companies, which receive complimentary access to, and involvement with, the annual summit. For more information about joining NYU WIRELESS as an Industrial Affiliate member, please visit nyuwireless.com.

As in past years, the Brooklyn 5G Summit was live-streamed throughout the world, and videos of the conference are available courtesy of IEEE Communications Society at nyuwireless.com/watch-brooklyn-5g-summit-2019. 

1. *Nokia CEO Rajeev Suri addressing the Summit in real time from Finland*
2. *(l. to r.) Tommi Uitto, President of Mobile Networks for Nokia; Marcus Weldon, CTO of Nokia and President of Nokia Bell Labs; Dr. Irwin Jacobs, Co-Founder and former Chairman of Qualcomm*
3. *(l. to r.) Peiyang Zhu, 5G Systems Research, Huawei; Professor Andrea Goldsmith, Stanford University; Professor Elza Erkip, NYU WIRELESS*
4. *Participant at the Imeve/Avatour VR/AR demonstration*
5. *(l. to r.) Ted Rappaport and Dr. Irwin Jacobs participate in a fireside chat at the New York Academy of Sciences.*
6. *(r.) NYU WIRELESS Ph.D. student Yunchou Xing explains his poster to a student.*
7. *Bill Stone, Vice President, Verizon*
8. *(l. to r.) Amitava Ghosh, Fellow, Nokia Bell Labs; Ted Rappaport, Founding Director, NYU WIRELESS*
9. *Summit participants visit the Blue Danube exhibit.*





NYU WIRELESS Welcomes CACI

CACI, which was previously known as Consolidated Analysis Centers, Inc. before officially changing its name to CACI International Inc., is the newest corporate member of the NYU WIRELESS Industrial Affiliates program, bringing the number of member companies to 16. CACI, with global headquarters based in Virginia, focuses on ways to support national security and provide the U.S. Government with cutting-edge

research and technologies. The company also assists the U.S. government in improving business solutions and productivity, in addition to enhancing connectivity and communications systems. CACI comes to NYU WIRELESS through the recent acquisition of LGS Innovations, a leading supplier of federal research and development, which was acquired by CACI for \$750 million in March 2019. We are delighted to welcome CACI to the NYU WIRELESS community and are certain they will bring valuable knowledge and experiences to the NYU WIRELESS board. **W**

Making the Most of the Summer—A Student’s Life

The research mission of NYU WIRELESS is based upon our six thrust areas of wireless innovation, which are developed between our faculty and Industrial Affiliate board members. The research is accomplished through the dedication, ingenuity, and hard work of our students, who we see are already becoming the next generation of wireless leaders. Our annual Open House and Recruiting Day, held on the fourth Friday of each January (for example, our next Open House is on Jan. 24, 2020), is designed to establish relationships between these future leaders and our Industrial Affiliate member companies.

Many of our Industrial Affiliates have hosted NYU WIRELESS students for internships, and 2019 was no exception. One graduate student who left New York City to explore work at an Industrial Affiliate member was Yunchou Xing, a Ph.D. student of Ted Rappaport. According to Yunchou, “I had a summer internship at Nokia Bell Labs and studied the topic of THz Channel modeling for above 100 GHz. There were also many other interesting projects related to 3GPP Releases 16 & 17, such as NTN (non-terrestrial networks), MIMO (multiple-input and multiple-output) enhancements, and other topics. I learned a great deal during the internship and enjoyed meeting other people, students from other universities, and the leadership at Nokia.” **W**



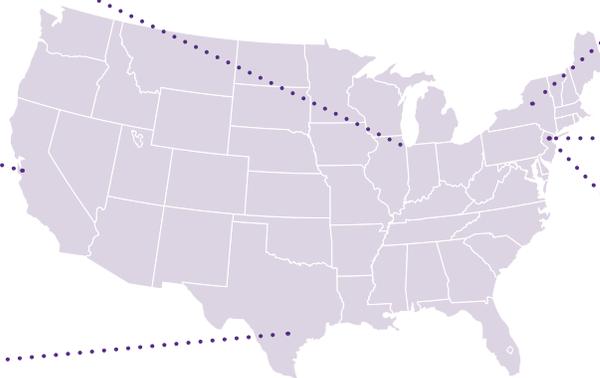
Yunchou Xing
Nokia Bell Labs
Naperville, IL



Jyotish Robin
Qualcomm
Santa Clara, CA



Ojas Kanhere
AT&T, Austin, TX



Chris Slezak
Air Force Research Lab
Rome, NY



Hangsong Yan
Nokia Bell Labs
Murray Hill, NJ



Manali Sharma
Nokia Bell Labs
Murray Hill, NJ



Professor Elza Erkip Recognized

NYU WIRELESS Institute Professor Elza Erkip was recently named to Crain's New York's inaugural Notable Women in Tech roster, along with the Dean of NYU Tandon School of Engineering, Jelena Kovačević.

This honor is the latest recognition of Elza's numerous accomplishments. Her recent achievements include receiving the IEEE Communications Society Communication Theory Technical Committee Technical Achievement Award in 2018, a best paper award from IEEE ComSoc in 2019, and the Women in Communications Engineering Award in 2016. Elza is also a Fellow of IEEE and a member of the Science Academy Society of Turkey.

Currently partnering with NYU Tandon School of Engineering co-investigators Sidharth Garg and Farhad Shirani Chaharsooghi



Elza Erkip

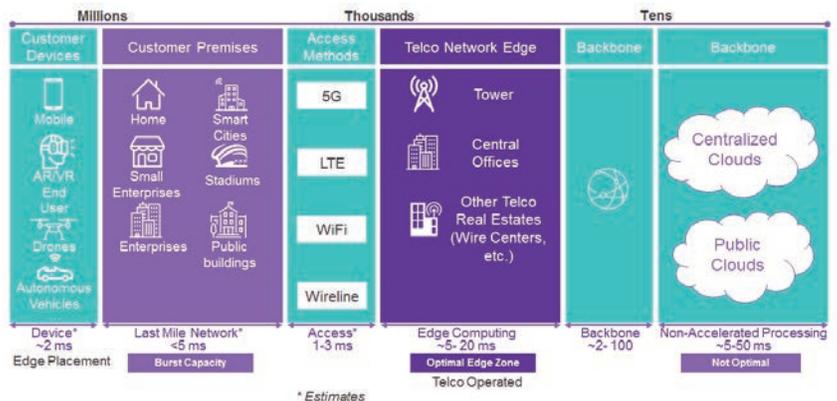
on an NSF-funded research project titled "An Information Theoretic Framework for Web Privacy," Elza and the team are investigating web privacy from an information theoretic perspective.

Their goal is to develop a unified framework to quantify the privacy risk that web users face from online attacks. They are also striving to determine the likelihood with which users on the internet can be identified from their online activities or their wireless network usage patterns.

Elza's work is focused on information theory, as well as communication theory and applied probability and statistics to better understand the theoretical foundations of wireless networks and social networks. Elza, along with Tom Marzetta, provides leadership in the communication fundamentals thrust area within NYU WIRELESS. More information about Elza can be found at NYUWIRELESS.com/people.

Open Source Mobile Edge Computing Launched at NYU

On June 27, 2019, NYU WIRELESS hosted the launch event for Edge Stack, an open source software platform for Mobile Edge Computing (MEC). Edge Stack has been developed by Akraino in collaboration with AT&T and the Linux Foundation. Vital for 5G wireless networks and beyond, MEC is a key enabling technology to deliver very low delay wireless communications for emerging cloud-based applications. MEC is expected to be particularly essential in 5G and 6G mmWave and THz networks to exploit the multi-gigabit per second air interface data rates. The Edge Stack platform will enable researchers at NYU WIRELESS to quickly develop end-to-end applications hosted in the mobile cloud. At the launch of Edge Stack, NYU WIRELESS Associate Director Sundeep Rangan presented a talk on using Edge Stack in the COSMOS testbed, a testbed funded by the National Science Foundation Platforms for Advanced Wireless Research (PAWR). The NSF COSMOS testbed is a large mmWave testbed in upper Manhattan that combines cloud computing with mmWave nodes. NYU WIRELESS participates along with Rutgers and Columbia in COSMOS, which is funded by NSF and the PAWR Industry Consortium.



Presentation from the open-source Akraino Edge Stack NYU launch event held on June 27, 2019. Participants included researchers from NYU WIRELESS, AT&T, Columbia, and the Akraino team.

FACULTY NEWS

Ludovic Righetti

NYU WIRELESS and the Tandon School of Engineering recently received the gift of a humanoid robot from the University of Southern California. Associate Professor Ludovic Righetti served as a postdoctoral fellow in USC's Computer Science Department earlier in his career and is now with NYU WIRELESS and the Departments of Electrical and Computer Engineering and Mechanical and Aerospace Engineering at NYU Tandon. The robot, named Hermes, who in Greek mythology was a mischievous messenger with many skills, is one of only four robots of this type made by Sarcos U.S., a world leader in robotics development. Hermes is the first full humanoid robot in the entire state of New York. Using Hermes, Ludovic is investigating



Ludovic Righetti

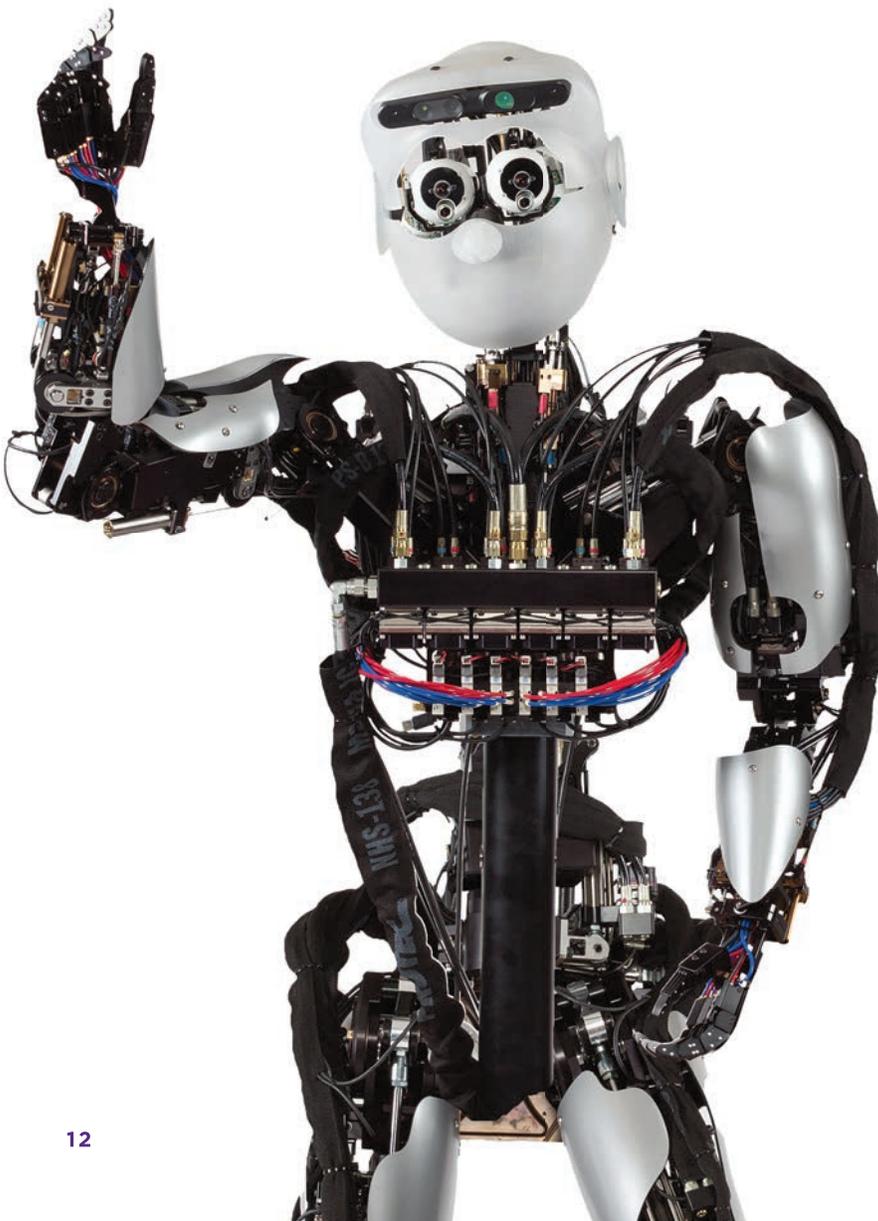
several areas that are of keen interest to 5G, including which algorithms will best facilitate a robot's walking without falling; how the robot can grasp objects without breaking them; and how it

can work safely around humans. Ultimately, the robot will be controlled over a 5G link within NYU WIRELESS, allowing real time understanding of latency, bandwidth, and robust control of robots over future wireless standards.

Professor Righetti also presented his work on 5G robotics in June at the workshop "Cloud and Fog Robotics in the Age of Deep Learning" at the Robotics: Science and Systems conference in Germany. This work is part of a project funded by NYU WIRELESS Industrial Affiliate Member OPPO, a leading cell phone maker based in China, and was done in collaboration with NYU WIRELESS faculty members Sundeeep Rangan and Siddharth Garg. Ludovic's student Huaijiang Zhu presented a poster at the conference on novel methods for control over 5G. Additionally, Ludovic received a Google Faculty Research Award that will be used to conduct research on "Bridging the Reality Gap: Learning to Transfer Policies from Simulation to Real Robots."

Mike Knox

NYU WIRELESS Industry Professor Michael Knox won the Best Conference Paper award at the IEEE WAMICON (Wireless and Microwave Technology Conference) held April 8-9, 2019, for the paper "Simplified Tapped Delay Line Architecture for Active Cancellation in a 2x2 IBFD MIMO Transceiver." The conference focused on simulation-driven design of wireless systems. He also won the award for Best Conference Paper the previous month at the IEEE IWAT (International Workshop on Antenna Technology) for his paper "Passive Interference Cancellation in a 2x2 STAR MIMO Antenna Network."





Giuseppe Loiano

Giuseppe Loiano

NYU WIRELESS Assistant Professor Giuseppe Loiano, of the Agile Robotics and Perception Lab at NYU Tandon School of Engineering, is co-organizing a workshop on Nov. 8, 2019, at the International Conference on Intelligent Robots and Systems (IROS 2019), which will be held in Macau. Titled “Challenges in Vision-Based Drones Navigation,” the workshop is being organized together with Professor Davide Scaramuzza from the University of Zurich. The workshop will discuss the research issues in the area of vision-based navigation for single and multiple collaborative vision-based drones. Drones are an important use case for future 5G wireless networks, as they will be used for remote monitoring, safety inspections, package delivery, and emergency response activities. More information can be found on the web at wp.nyu.edu/workshopiros2019mav/.

Sundeep Rangan

NYU WIRELESS Associate Director Sundeep Rangan was the co-author of a paper that won the Jack K. Wolf Student Best Paper Award at the 2019 IEEE International Symposium on Information Theory (ISIT) held in Paris, France, in July 2019. The paper, “Asymptotics of MAP Inference in Deep Networks,” is a joint collaboration with Assistant Professor Alyson K. Fletcher



Sundeep Rangan

of UCLA through a grant from the National Science Foundation. IEEE ISIT is the premier conference in information theory, and the paper was selected for recognition from over 630 final accepted manuscripts. Deep generative models have had enormous practical success in reconstruction problems with complex data such as images and text. However, mathematical analysis of these algorithms has been difficult. The paper provides a powerful new tool for understanding reconstruction with deep generative models.

Marco Mezzavilla

NYU WIRELESS researchers, led by Research Scientist Marco Mezzavilla, have recently been awarded Best Journal Paper from the IEEE ComSoc Technical Committee on Communications Systems Integration and Modeling 2019. The paper, “End-to-End Simulation of 5G mmWave Networks,” appeared in *IEEE Communications Surveys & Tutorials*, the leading journal in this field. This work was conducted in collaboration with the University of Padova and a number of NYU WIRELESS



Marco Mezzavilla

Industrial Affiliate Member companies and represents the world’s first end-to-end 5G mmWave simulation platform. The tool, called mmWave Cellular Network Simulator, is open source and has already been downloaded by thousands of researchers all around the globe. It can be obtained at apps.nsnam.org/app/mmwave/. NYU WIRELESS is working constantly to provide cutting-edge tools for the global wireless research community, and offers other platforms, such as NYUSIM (nyuwireless.com/nyusim) for wireless channel simulation. In the end-to-end platform, mmWave Cellular Network Simulator, the aim is to provide researchers with a flexible platform to design and test full-stack algorithms in a variety of mmWave-enabled scenarios, including cellular, aerial, automotive, and robotics. 

NYU WIRELESS Faculty, Post-Docs, and Research Engineers



Theodore Rappaport
Founding Director,
ECE, CS, Med.



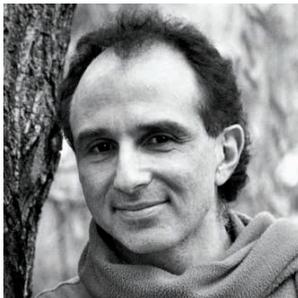
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Associate Director, ECE



Sundeeep Rangan
Associate Director, ECE



John-Ross Rizzo
Associate Director,
NYU Langone Health



Dennis Shasha
Associate Director, CS



Henry Bertoni
Professor Emeritus, ECE



Aditya Dhananjay
Postdoctoral Associate, ECE



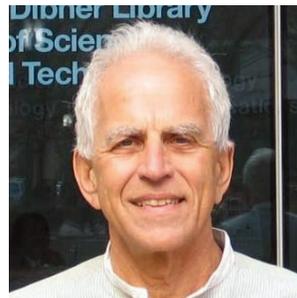
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Postdoctoral Associate



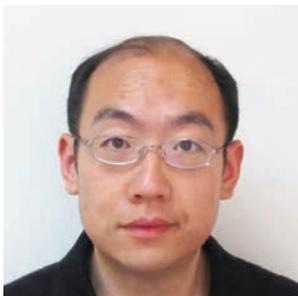
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Research Scientist, ECE



Yong Liu
Associate Professor, ECE



Giuseppe Loianno
Assistant Professor



Marco Mezzavilla
Research Scientist, ECE



Shivendra Panwar
Professor, ECE



Ludovic Righetti
Associate Professor, ECE & MAE



Davood Shahrjerdi
Assistant Professor, ECE



Farhad Shirani
Research Assistant Professor,
ECE



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Yao Wang
Professor, ECE & BioMed

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HOLD THE DATES

NYU WIRELESS Industrial Affiliate Activities

Fall 2019 Industrial Affiliates Mini-Lectures, 12:15pm
October 30, 2019 • November 13, 2019 • December 18, 2019

Industrial Affiliates Open House and Recruiting Day,
January 24, 2020

NYU WIRELESS Board Meeting, April 21, 2020

Brooklyn 5G Summit, April 21-24, 2020

NYU WIRELESS

Recent Publications

January–August 2019

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T.S. Rappaport, Y. Xing, O. Kanhere, S. Ju, et al., “Wireless Communications and Applications Above 100 GHz: Opportunities and Challenges for 6G and Beyond,” in *IEEE Access*, vol. 7, pp. 78729-78757, June 2019

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NYU WIRELESS Newsletter

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NYU WIRELESS Recent Publications

January–August 2019, *Continued*

D. Thakur, G. Loiano, W. Liu, V. Kumar, “Nuclear Environments Inspection with Micro Aerial Vehicles: Algorithms and Experiments,” arXiv:1903.06111, Mar. 2019

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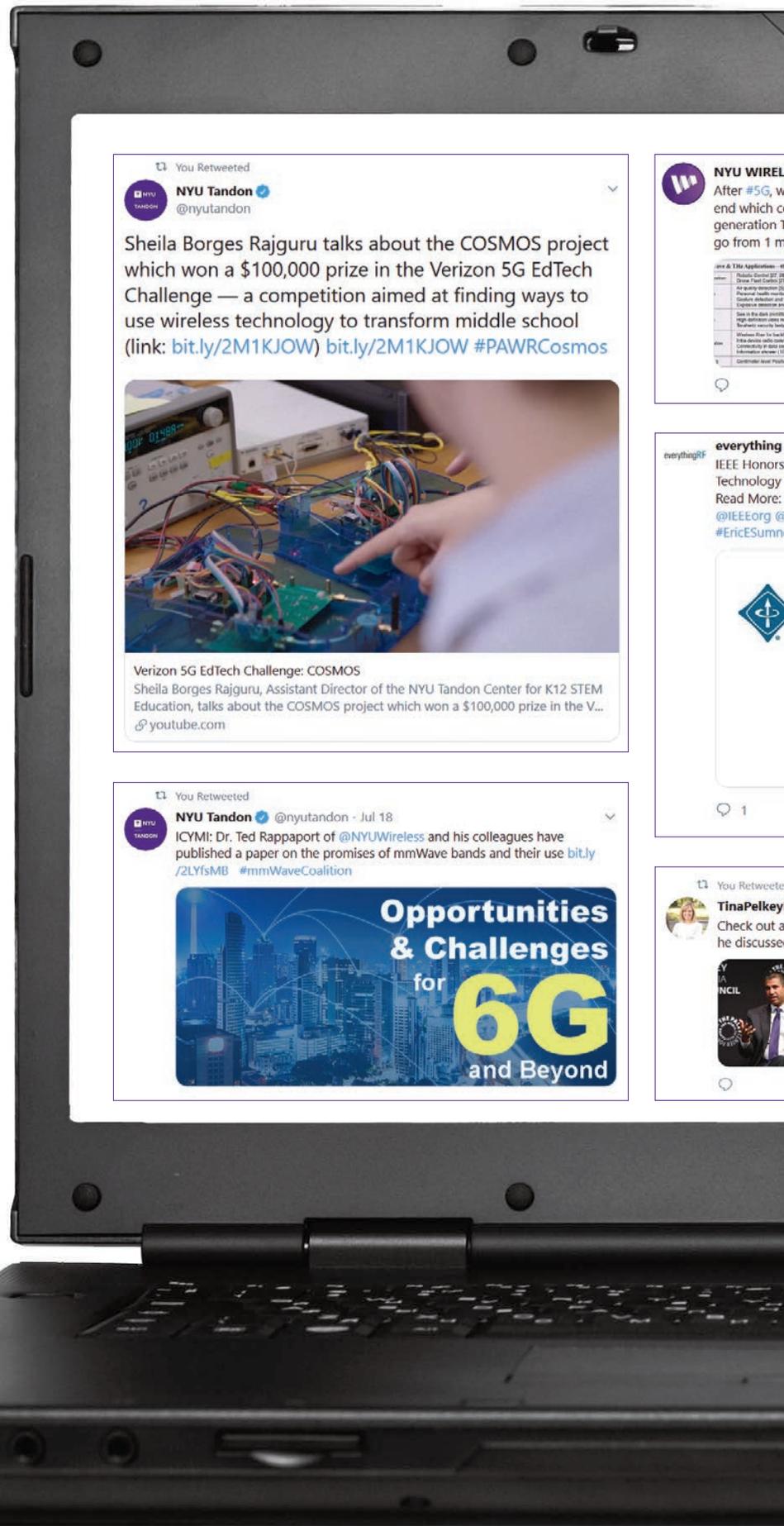
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At the Brooklyn 5G Summit 2019, NYU Professor Ted Rappaport, whom I consider a communication ...
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Theodore Rappaport, EECS professor at NYU Tandon School of Engineering and founder of @NYUWireless, has received two awards for his research that has led to the development of #5G. See full coverage @eetimes #NYUTandonMade #VioletPride

NYU Wireless Director Honored Twice
Theodore S. Rappaport has received an award from IEEE and will be inducted into the Wireless History Foundation's Hall of Fame.
eetimes.com

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FCC @TinaPelkeyFCC · Jun 21

Recap of @AjitPaiFCC's visit to the @paleyMC this week, where he discussed tech issues with Ted Rappaport of @NYUWireless.

AJIT PAI ADDRESSES THE PALEY MEDIA COUNCIL
FCC Chairman Addresses Important Technology Issues Including Net Neutrality, 5G, and Navigating ...
globenewswire.com

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Blavatnik Awards @BlavatnikAwards · Jul 16

2010 Regional Award Faculty Finalist Prof. Elza Erkip @nyuniversity Tandon School of Engineering helps us understand 5G networks and social network privacy #Blavatnik2019 Science Symposium @Nyasciences bit.ly/2kbZ2Vo



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