

NYU WIRELESS PULSE

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Cover Photo: NYU Tandon Dean Jelena Kovačević applauds new students at orientation (Sept. 2018)



The world's first academic research center combining Wireless, Computing, and Medical Applications.
www.nyuwireless.com

About NYU WIRELESS

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

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

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WELCOME FROM THE DIRECTOR

In August 2012, when a handful of faculty founded NYU WIRELESS, my students and I had in our possession the world's first massive collection of 28 GHz propagation data from the streets of New York City. We knew that millimeter wave wireless communications would work better in mobile environments than anyone would believe, and we were convinced that millimeter wave spectrum was the only way the wireless world could keep up with consumer demand. A handful of companies believed in our vision, and our first generation of NYU WIRELESS students pioneered the theory, simulations, and measurements that proved to the world that, indeed, 5G would be the millimeter wave era. Those students are now working at many of our Industrial Affiliate companies, leading the way to 5G commercialization.

I had the honor and privilege of serving as the founding director of NYU WIRELESS from 2012 through 2015, and watched our center rapidly grow during those years, from a relatively unknown research group at Brooklyn Polytechnic to a globally renowned wireless research center. By 2015, when I stepped down as director, we had about 10 major companies on our In-

dustrial Affiliates board, and the merger between NYU and Brooklyn Polytechnic was nearly complete. Professor Sundeep Rangan took the helm and masterfully continued to grow the center, with the addition of terrific new faculty, major U.S. government awards, and new affiliate sponsors and research thrusts. Over the past few years, NYU's graduate ranking in engineering has ramped rapidly, from 68 to 42, with NYU WIRELESS helping to attract top students and faculty to our campus. Now, six years after launching our center, I believe the best is yet to come.

As I return to the directorship of NYU WIRELESS, I am amazed at how the collective efforts of our faculty, students, and staff have aided our Industrial Affiliate sponsors to create a completely new wireless standard, 5G New Radio, which is delivering multi-gigabit-per-second data to customers. I marvel at the contributions of knowledge that our students and faculty are producing for our sponsors and the research community at large (see the pages 17 - 22 of this newsletter for recent publications). A visioning exercise with our faculty and Industrial Affiliates helped us identify the major challenges for the next decade of wireless, and we have identified six major



Prof. Ted Rappaport, Director of NYU WIRELESS
core thrusts for NYU WIRELESS faculty and students in the coming years (see "NYU WIRELESS Welcomes Back Students with a Visit from the Dean" on page 14). Already, we have secured major funding from federal agencies and our Industrial Affiliates in all of these six thrust areas. As we look to the future of wireless, I invite you and your organization to become part of the excitement at NYU WIRELESS.

*Prof. Ted Rappaport
Director of NYU WIRELESS*

NYU WIRELESS ROTATES DIRECTORSHIP: POISED FOR NEW GROWTH

Professor Theodore (Ted) Rappaport, founding director of NYU WIRELESS, has stepped back into the director role of the research center. Assisting Professor Rappaport will be Associate Directors Professor Sundeep Rangan, and Professor Thomas Marzetta of the ECE department, Professor Dennis Shasha from NYU's Courant Institute for Mathematical Sciences, and Assistant Professor J.R. Rizzo from NYU Langone Health.

Professor Rangan admirably served as director for the past three years of successful operations of NYU WIRE-

LESS, spearheading the center through a very busy time. He worked with all the center's Industrial Affiliate partners, which have taken the mmWave propagation, theoretical analysis, and system design research conducted at NYU to create the 5G technologies that are now set to revolutionize wireless communications, as well as other industries and products that benefit from mobile connectivity.

Amplifying the support from our Industrial Affiliates, several NYU WIRELESS investigators recently received research awards of note. These include

the COSMOS platform, which is part of the PAWR initiative (Platforms for Advanced Wireless Research) funded by the National Science Foundation. COSMOS is a testbed for a new generation of wireless technologies and applications. NYU WIRELESS Associate Director Professor Rangan is leading the project at NYU Tandon School of Engineering, together with colleagues Professor Shivendra Panwar and Research Assistant Professor Thanasis Korakis, as well as with researchers at Rutgers and Columbia in partnership (continued on page 13)



Fourth Annual RCN mmWAVE Conference Held at NYU WIRELESS

*NSF-Sponsored Event Aimed to Spur R&D of mmWave Wireless in Three Areas:
Communication and Signal Processing Techniques,
mmWave Hardware, and Wireless Networking*

NYU WIRELESS was pleased to host RCN's semiannual workshops, on July 12-13, 2018. The NSF-funded Millimeter-Wave Research Coordination Network (RCN) focuses on mmWave wireless networks, and how to best ensure that all aspects of this technology benefit from a coordinated approach to ongoing research. This includes input from indus-

try and academia in the areas of communication and signal processing techniques; mmWave hardware, circuits, antennas, and digital hardware; and wireless networking protocols. With the goal of guiding and accelerating mmWave wireless technology and standards, the group met for two days of talks and break-out sessions on the NYU Tandon School of Engineering campus.

NYU WIRELESS' Associate Director Sundeep Rangan, one the members of the RCN steering committee, was the local host for the meeting, which is chaired by Akbar Sayeed from the University of Wisconsin-Madison.

The steering committee is comprised of 16 leading mmWave researchers from industry and academia, and includes participants from the European mm-MAGIC Project and the NIST 5G Channel Modeling Alliance. The group encourages participation in the workshops so that the state-of-the-art in mmWave R&D technology can advance, with many different perspectives represented.

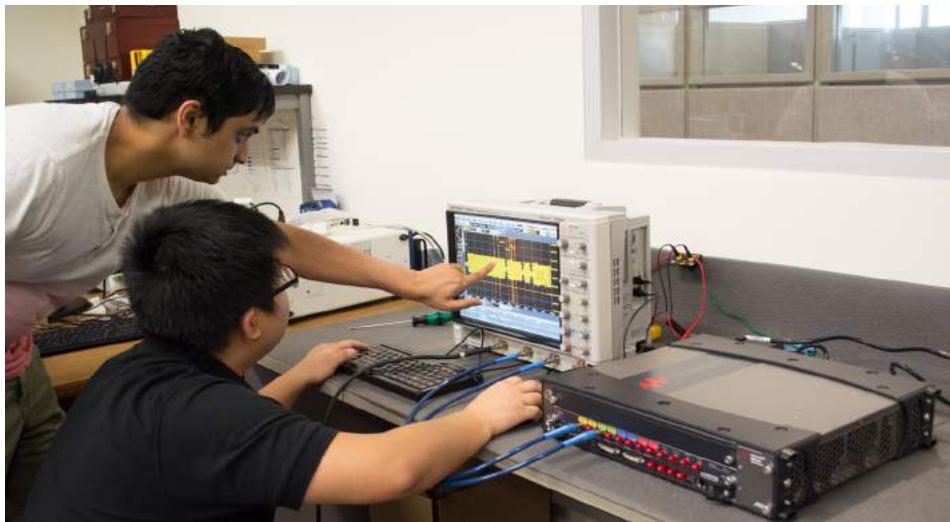
Workshops are held twice a year, with the next one scheduled for January 28-29, 2019 in Raleigh, NC. Past workshop lectures are available on the group's YouTube channel, *Millimeter-Wave RCN*. The group's web site is mmwrcn.ece.wisc.edu.



Dr. Peter Moosbrugger (Ball Aerospace) presented the HW-CSP Interface: Hardware, Circuits, Antennas, Communication/Signal Processing, & Prototypes/Testbeds

KEYSIGHT DONATES LARGEST IN-KIND GIFT TO NYU WIRELESS AND NYU TANDON ENGINEERING SCHOOL

Cutting-edge Donation Futhers NYU WIRELESS' Path to Leadership in Terahertz Spectrum



Graduate students Ojas Kanhere (left) and Yunchou Xing use the newly donated Keysight equipment

As the industry begins to look beyond 5G, Keysight Technologies, Inc., has made a timely donation that will further NYU WIRELESS' exploration of mmWave and Terahertz (THz) electromagnetic spectra for ultra-fast and high-capacity data transmission.

The gift, made through the **Keysight University Relations** program, is the largest ever for NYU WIRELESS and the largest in-kind donation in the history of the NYU Tandon School of Engineering.

The donation brings together two powerhouses in the race to create new technologies, not only for communications, but for medical imaging, pharmaceutical monitoring, semiconductor testing, new kinds of spectroscopy, and for applications such as synchronized clouds of "smart dust" detectors.

Included in the gift is an array of cutting-edge equipment — including measurement capability up to 110 Gigahertz (GHz) — that promises to accelerate one of the six major thrust areas of NYU WIRELESS: THz communica-

tions and sensing beyond 5G wireless systems.

Keysight, a participant in the creation of the 5G wireless ecosystem worldwide, has been a member of the NYU WIRELESS Industrial Affiliates program since late 2014. Keysight's customers span the worldwide communications ecosystem, aerospace and defense, automotive, energy, and semiconductor and general electronics end markets to help enterprises, service providers, and governments accelerate innovation to connect and secure the world.

"Within six short years, NYU WIRELESS created an internationally recognized hub in Brooklyn that propelled the adoption of technologies that will touch nearly every aspect of our digital lives," said NYU Tandon Dean Jelena Kovačević. "It is exciting to watch as NYU Tandon faculty and students from across the University help drive the next great challenges facing wireless communications."

"The generosity of Keysight, a long-standing industrial affiliate partner of NYU

WIRELESS, will bring cutting-edge equipment to students and faculty, helping us write our most exciting chapter yet: advanced research into the rarefied areas of the electromagnetic spectrum above 100 GHz," NYU WIRELESS Director Ted Rappaport said. "Our student and faculty researchers, as well as our Industrial Affiliate sponsors and the research community at large, will all benefit from this gift."

Roger Nichols, 5G program manager at Keysight Technologies, as well as a member of NYU WIRELESS' advisory board, explained that the gift aims to identify and encourage collaborative research in the most promising technologies. In addition to the gift, he and his extended team will serve as mentors to NYU WIRELESS students.

"We are excited to be part of what the team at NYU is doing," Nichols said. "Our work in 5G with market and technology leaders such as Dr. Rappaport has been instrumental in enabling an entire ecosystem to make 5G a reality. As part of the advisory board, I have been inspired watching Ted, his team, and his associates enlighten and enliven the dialogue to make mmWave ready for mainstream communications. Keysight is committed to the future of 5G, as well as enabling broader adoption of mmWave technologies."

The gift includes:

- **mmWave and broadband Signal analysis and generation capabilities**
- **Advanced Time-domain analysis**
- **RF/mmWave Power measurement**

JELENA KOVACHEVIĆ NAMED DEAN OF TANDON SCHOOL OF ENGINEERING

First Woman Dean in 164-Year History of Brooklyn-based Engineering School

Is that Dean Kovačević zipping by on an electric bicycle? It wouldn't surprise anyone if it were. Since taking charge of Tandon School of Engineering as Dean in August, she has been appearing at multiple events all around campus and meeting scores of researchers, students, and staff. As the first woman dean in the school's history, she is well positioned to take NYU's Tandon School of Engineering to the next level, and to encourage female students to enroll in Tandon and to enter STEM fields after graduation.

Dean Kovačević came to Tandon from Carnegie Mellon University, where she was the Hamerschlag University Professor, the head of the Department of Electrical and Computer Engineering, and a professor of biomedical engineering. As NYU's President Andrew Hamilton said, "One of NYU's historic strengths is setting high ambitions for itself, and finding the right leaders to achieve them. In Jelena Kovačević, we have found just such a person.

"She impressed us not just with her scholarship, but also with her thoughtful approach to strategy, leadership, and execution; the future of the engineering profession and education; and the promise of Tandon's Brooklyn location and NYU's global outlook. We were also struck by her down-to-earth manner, her resolve, and - a crucial requirement for life in New York - her warm sense of humor.

Professor Kurt Becker, the Chair of the Search Committee, said, "Professor Jelena Kovačević stood out among the large number of candidates as the best one to leverage the significant progress that Tandon has made in the last few



Prof. Jelena Kovačević, Dean of NYU Tandon School of Engineering

years and take the school to an even higher level. The committee felt that her achievements as head of a top-ten department in a top-ten engineering school made her uniquely qualified to be the next leader of our school, and a great asset to the university and the borough of Brooklyn."

Chandrika Tandon, chair of the Tandon Board of Overseers and vice chair of the NYU Board of Trustees, commented that, "The investment in engineering and applied sciences is a flagship initiative for NYU. The School of Engineering has been on a rapid trajectory of transformation. Accelerating that momentum is vital to the future of the school. We are all truly excited that Jelena will bring her extraordinary leadership, vision, energy, and execution abilities and vault us forward."

According to Dean Kovačević, "It is an honor to serve as dean of the Tandon School of Engineering. I am thrilled to join a community widely known for its venerable history in the field of engineering, its deep connection to Brooklyn, its vibrancy and diversity, and its upward trajectory. I look forward to working together with everyone at Tandon to achieve everything we dream of for the school."

Prior to her positions at Carnegie Mellon, Dean Kovačević worked at Bell Laboratories as a member of the technical staff in the signal processing research department, and later as a member of the mathematics of communications research department.

The Dean's research interests include applying data science to a number of domains, such as biology, medicine, and smart infrastructure, and she is an authority on multi-resolution techniques, such as wavelets and frames. She is the author or co-author of several books and many scholarly articles in reviewed engineering journals. She also has 21 patents to her name and has received many honors and awards. She received her undergraduate degree in electrical engineering from the University of Belgrade, and her MS and Ph.D., also in electrical engineering, from Columbia University.

Dean Kovačević has said that Tandon "...has this incredible opportunity to make an impact, and already is — which is what impressed me so much — on Brooklyn, on entrepreneurship, on innovation." And she is just beginning to play a large part in making that impact, as well.

STUDENTS WIN BEST STUDENT PAPER AWARD AT IEEE VTC



From left to right, Shihao Ju, Ted Rappaport, Yunchou Xing, and Ojas Kanhere at the Fall 2018 IEEE Vehicular Technology Conference in Chicago

Professor Rappaport's students won the best student paper award at the 2018 IEEE Vehicular Technology Conference, held in Chicago in August 2018. Winning the award were Yunchou Xing, Ojas Kanhere, Shihao Ju, and George MacCartney, Jr. The paper, "Verification and Calibration of Antenna Cross-Polarization

Discrimination and Penetration Loss for Millimeter Wave Communications," examined standardized measurement guidelines and verification procedures for antenna cross-polarization discrimination (XPD) and penetration loss measurements.

The proposed methods would ensure that accurate XPD and

penetration loss measurements can be replicated by anyone at any frequency or bandwidth. Measurements at 73 GHz were used to demonstrate and verify the proposed guidelines, providing a systematic method that can be used at any frequency for reliable field measurements.

WIRELESS UPDATES FOR INDUSTRIAL AFFILIATE MEMBERS

NYU WIRELESS is excited to launch a new set of mini-lectures as part of our Industrial Affiliates Program. These lectures present cutting-edge topics in easily watchable formats, which are archived for later viewing by all employees of every Industrial Affiliate sponsor of NYU WIRELESS.

Please visit nyuwireless.com/faculty-seminar-series or contact info@nyuwireless.com for more information.

If your company would like to join NYU WIRELESS, please visit nyuwireless.com/industrial-affiliates to learn more about our Industrial Affiliate program.

We welcome feedback on the sessions. Please let us know if there are additional topics you would like to see covered.

DATE	SPEAKER	TOPIC
Sept 12, 2018	Ted Rappaport	Spatial Consistency, Position Location and Channel Sounding above 100 GHz
Sept 26, 2018	Sundeep Rangan	Network and System Challenges for mmWave and THz Networks
Oct 10, 2018	Yao Wang	Machine Learning for Image Compression and Visual Analytics
Oct 17, 2018	Lakshmi Subramanian	Recent Projects in Urban Data Science: A Quick Summary
Oct 31, 2018	Elza Erkip	Information Theoretic Perspective on Network Privacy
Nov 14, 2018	Shivendra Panwar	Millimeter Wave Millisecond Delay Networks
Nov 28, 2018	Davood Shahrjerdi	Security Engineering Based on Atomically Thin Layered Transition Metal Dichalcogenides
Dec 5, 2018	J.R. Rizzo	Intelligent Cognitive Assistants that Can "See"

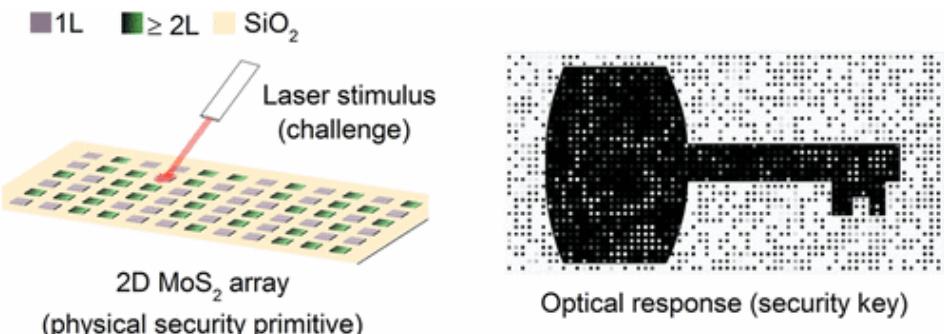
MANUFACTURING RANDOMNESS

NYU WIRELESS Paper Highlighted by *Nature Nanotechnology*

The globalization of supply chains has undermined trust in electronic products, which were once manufactured by a few trusted factories. The use of embedded security tags, called *taggants*, is expected to restore trust and protect products from counterfeiting. A recent study by NYU WIRELESS PhD student Abdullah Alharbi and team, working under Professor Davood Shahrjerdi, introduces an innovative security engineering approach based on a new class of two-dimensional nanomaterials, called *transition metal dichalcogenides* (TMDs).

This security taggant technology takes advantage of two unique properties of synthetic TMDs to construct physically unclonable security taggants.

The first property is the complete spatial randomness of the TMD is-

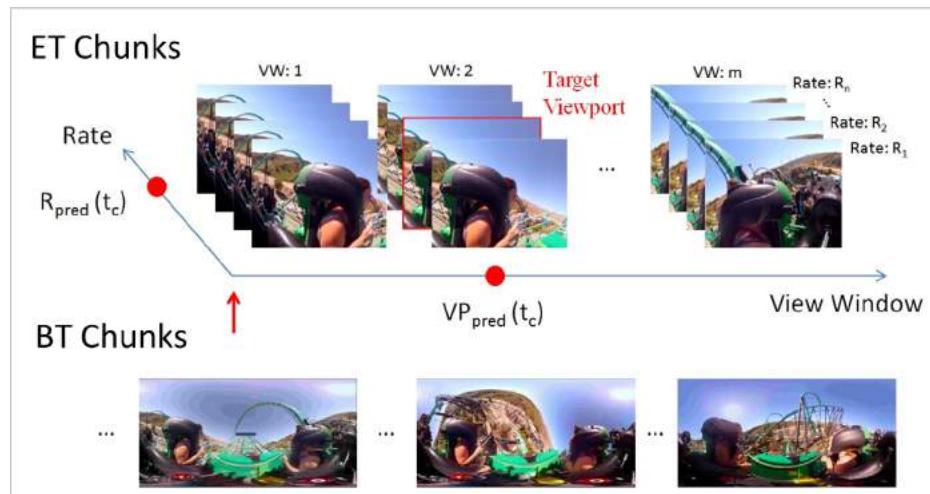


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land growth, which is fundamental to the material growth using chemical vapor deposition. The second property is the strong dependence of the photo-emission on the number of TMD layers. This property is unique to this class of nanomaterials, where depending on the number of layers, the TMD film acts as either an emitting or a non-emitting semiconductor.

These nano-taggants have an atomic thickness, which makes them substrate agnostic, and are easy to verify. These features make the TMD-based nano-taggants promising for unique identification of a wide range of valuable goods from pharmaceutical products to electronic devices.

NSF AWARD RECIPIENTS TO STUDY 360° VIDEO



NYU WIRELESS professors Yong Liu and Yao Wang received a three-year grant worth \$0.5 million from the National Science Foundation to study 360° video, which is often used in virtual reality and augmented reality applications. 360° video streaming requires

much higher network bandwidth and much lower packet delivery latency when compared with traditional video streaming. This project will address such challenges, developing novel 360° video coding and delivery solutions to enable high quality interactive, on-demand, and live video streaming.

The project includes several research focus areas:

Interactive streaming - Novel Field-of-View (FoV) adaptive coding structure will be designed to achieve low encoding and decoding latency.

Personalized FoV prediction based on other users' view trajectories will also be explored under the framework of recommender systems.

Fully-functional 360° video streaming prototypes will be developed and tested in controlled and real network environments to validate and improve the new designs.

STREAMING LIVE THIS FALL: “CIRCUITS: TERAHERTZ AND BEYOND” — THE NEXT FRONTIER FOR COMMUNICATIONS AND ELECTRONICS

The next frontier for ultra-fast computing and wireless communications — the Terahertz electromagnetic spectrum — is being examined in a series of seminars by the foremost scientists and engineers in the field. Organized by NYU WIRELESS and NYU Tandon School of Engineering’s Electrical and Computer Engineering Department, the series at the school’s Brooklyn, New York, campus is streamed live for **NYU WIRELESS Industrial Affiliate sponsors** and the public, and is archived for public viewing.

“Circuits: Terahertz (THz) and Beyond” explores the vast unknown that lies between the optical spectrum and the millimeter wave (mmWave) frequencies that will soon carry massive amounts of data in 5G. Researchers have been working for decades, trying to solve fundamental challenges of the THz spectrum and pushing the boundaries of quantum nanoelectronics in the hope of unlocking even more gains for communications, computing, sensing, and materials.

“Recent breakthroughs in THz research, quantum computing, and nanotechnology have opened exciting new vistas for the future of electrical and computer engineering, and NYU has made major investments in these promising areas already,” said Professor Theodore (Ted) S. Rappaport, director and founder of NYU WIRELESS. “While we have pioneered the use and understanding of mmWave frequencies for 5G, it is clear that new knowledge will be needed



Dr. Aydin Babakhani presenting, “Silicon-based Integrated Sensors with On-chip Antennas” on 9/5/18

to bridge the gap between the fundamentals of these new areas with the design and fabrication of devices. In keeping with the NYU WIRELESS tradition, we also seek to amplify the global conversation in these exciting areas by organizing this series and making it free and open to all.”

“The spectrum also holds great promise for communications and networks—both strongholds of NYU Tandon research—as well as sensing and optics,” said Professor Ivan Selesnick, chair of the ECE department. “The THz seminar series reflects our commitment to both educate students and foster the pursuit of new, important research areas in electronics and wireless communication.”

“This new series will bring leaders in this emerging field of study to Brooklyn, to the benefit of our students, faculty, and all of New York, as well as scholars worldwide,” said NYU Tandon Dean Jelena Kovačević, whose academic background is in electrical and biomedical engineering. “Our faculty and NYU WIRELESS established Brooklyn as a world-renowned center for

mmWave technology, and the excitement is palpable here as they explore technologies that will drive communication and computing decades hence.”

The inaugural seminar, held on Wednesday, September 5, 2018, featured Aydin Babakhani speaking on “Silicon-based Integrated Sensors with On-chip Antennas: From THz Pulse Sources to Miniaturized Spectrometers.” An associate professor of electrical and computer engineering at the UCLA Henry Samueli School of Engineering and Applied Science and director of the Integrated Sensors Laboratory at UCLA, Babakhani’s research could have major implications for biomedical devices. For example, Babakhani designed a wireless, battery-free pacemaker that receives energy through radio frequency radiation and eliminates the need for risky surgeries to replace batteries.

All seminars begin at 11 a.m. eastern and can be watched at engineering.nyu.edu/live. For more information, visit the Electrical and Computer Engineering department at nyuwireless.com/circuits-terahertz-and-beyond.

Brooklyn 5G Summit 2019 (B5GS)

6th Annual Summit will Feature Latest Advances in 5G and Beyond

Each year the Brooklyn 5G Summit brings together thought leaders from academia, industry, and regulatory groups to discuss new directions and advances in wireless communications. The 2019 Summit will be especially exciting, as the rollout of 5G technology will have started in earnest. **The B5GS will take place from April 23 to 25, 2019 on the NYU Tandon School of Engineering campus in Brooklyn**, and is sponsored by NYU WIRELESS and **Nokia**, with livestreaming provided by IEEE ComSoc. On April 26, 2019, an optional visit is scheduled to **Bell Labs** in New Jersey.

Welcoming the attendees to the sixth year of B5GS will be

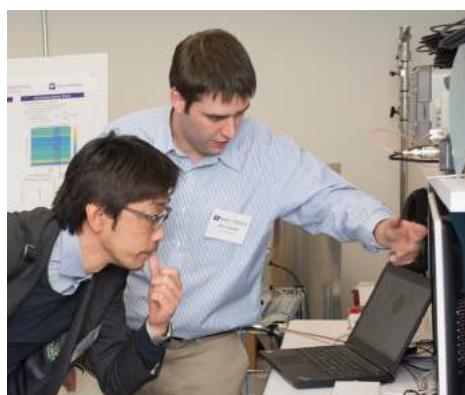
*View past years' conferences:
nyuwireless.com/b5gs*

Professor Ted Rappaport from NYU WIRELESS and Dr. Marcus Weldon, President of **Nokia Bell Labs** and Corporate Chief Technology Officer. Panel topics will include Terahertz communications, machine learning, non-terrestrial networks, discussions of 5G network deployment, and IoT technologies. Use cases in industrial automation and transportation will also be featured. Several leading CTO's, company presidents, and leading academics have already confirmed their participation.

In addition to the technical sessions, demos are always a compelling aspect of B5GS. The 2019 Brooklyn 5G Summit will include more time for attendees to visit the demos and posters. Start-up companies will again be featured in the demo hall.

Major themes at the 2018 Summit included the (a) speed at which new services and technologies will be rolled out; (b) the "edge cloud," which will become a major part of enabling 5G, since it can provide ultra-fast cloud services for computing and storage right next to mobile users, enabling new applications, especially in AI; and (c) the speed of the antenna technology evolution, with Massive MIMO and beam-forming combining with new chipset technologies to enable extreme speeds for both fixed and mobile access while reducing cost.

The 2019 B5GS promises to have cutting edge insights into the early 5G rollouts throughout the world, and new results and spectrum policy in Terahertz frequencies.



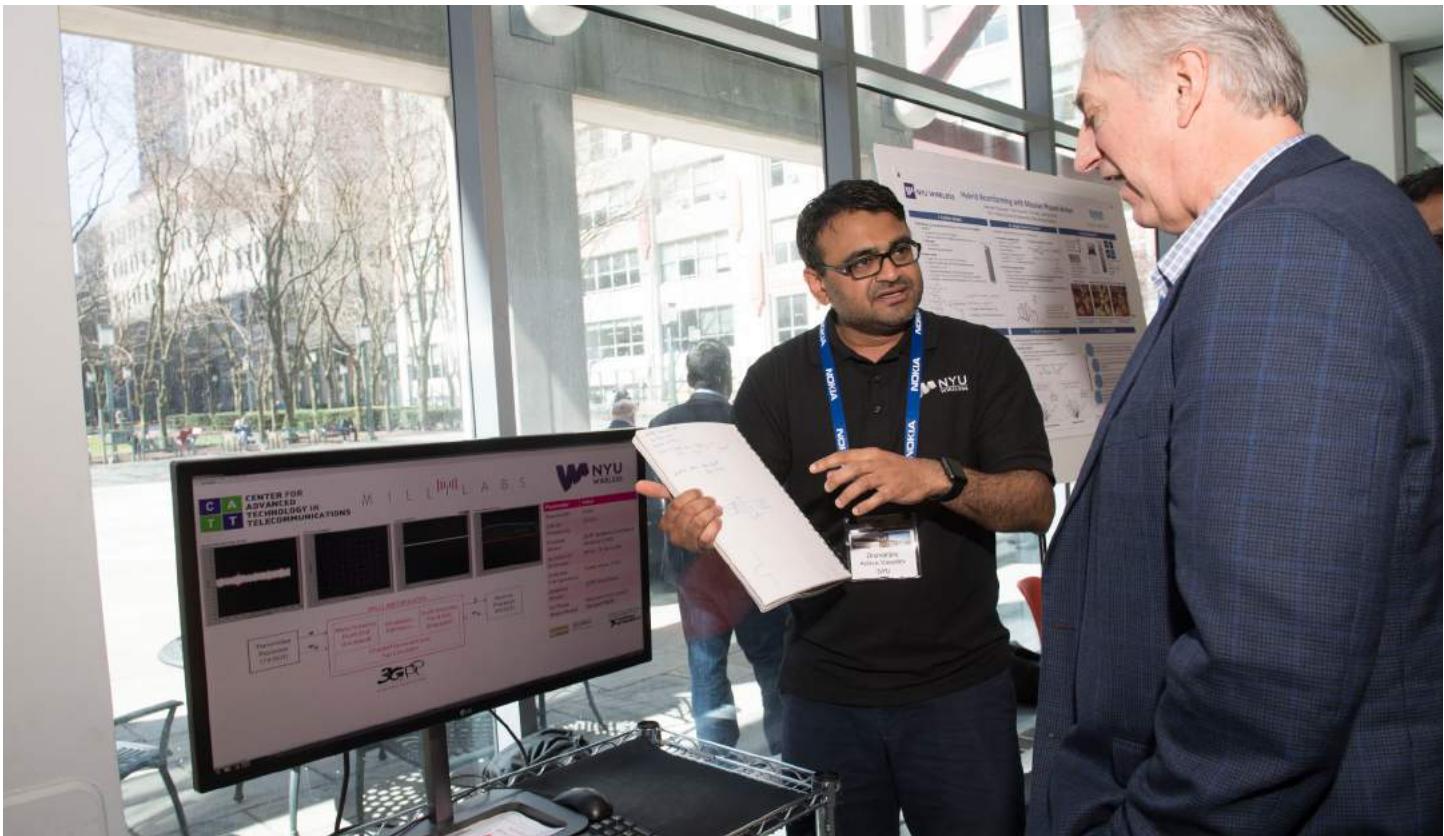
Kazuyuki Sakoda, an NYU WIRELESS Industrial Affiliate member from Sony, reviews results with PhD student Chris Slezak during 2018's Recruitment Day

NYU WIRELESS Spotlights Student Research on Recruitment Day

NYU WIRELESS Industrial Affiliate partners are invited on January 25, 2019 to meet with students to discuss their research projects and to see if there might be a fit for internships or positions. Our annual Recruitment Day is held each year in January and is a fast-paced dive into research currently underway at the center.

Posters and interactive demonstrations on topics such as mmWaves, channel modeling, Terahertz communications, and more are featured, as well as updates from faculty members. It's a great way for our Industrial Affiliates to get to know NYU WIRELESS faculty and students better, and to share information.

PHOTOS FROM B5GS 2018



Aditya Dhananjay, NYU WIRELESS Postdoctoral Associate, discussing his research with a B5GS attendee



Melissa Arnoldi, President, Technology and Operations, AT&T Communications



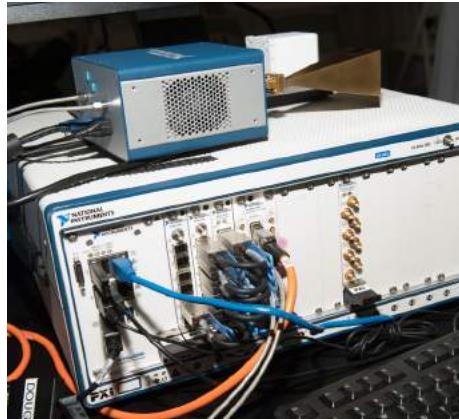
Marcus Weldon, President, Nokia Bell Labs and Corporate Chief Technology Officer



Amitava Ghosh, Head, Radio Interface Group, Standardization Research, Nokia Bell Labs and Ted Rappaport, Director, NYU WIRELESS



B5GS panelists discussing Future Transport: Integrated Access and Backhaul



A National Instruments channel sounder



Seizo Onoe, Chief Technology Architect at NTT DOCOMO, Inc. discusses the 5G bandwagon

NYU WIRELESS Faculty



Theodore Rappaport
Founding Director, ECE



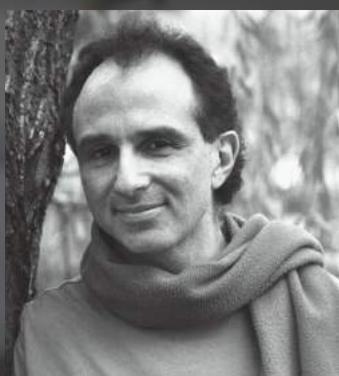
Thomas L Marzetta
Associate Director, ECE



Sundeep 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



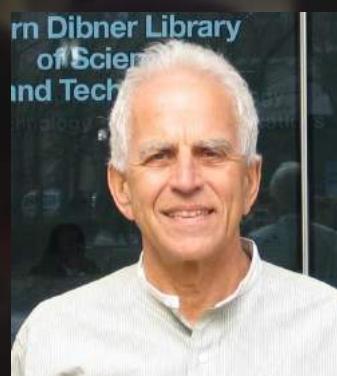
Elza Erkip
Institute Professor, ECE



Fraida Fund
Assistant Professor, ECE



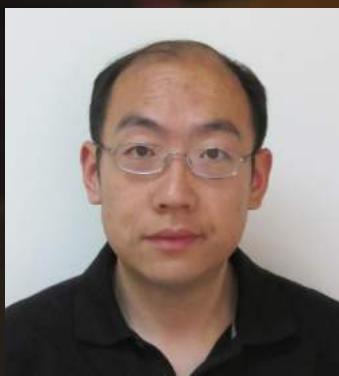
Siddharth Garg
Assistant Professor, ECE



David Goodman
Professor Emeritus, ECE



Michael Knox
Industry Professor, ECE



Pei Liu
Research Scientist, ECE



Yong Liu
Associate Professor, ECE



Marco Mezzavilla
Research Scientist, ECE



Shivendra Panwar
Professor, ECE

NYU WIRELESS Faculty



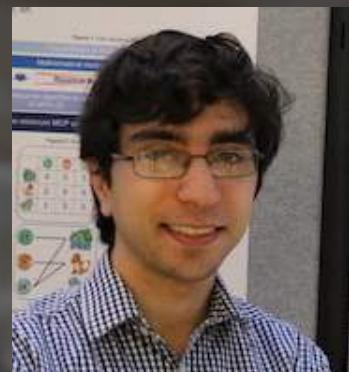
Shaloo Rakheja
Assistant Professor, ECE



Ludovic Righetti
Associate Professor, ECE & MAE



Davood Shahrjerdi
Assistant Professor, ECE



Farhad Shirani
Research Assistant Professor, ECE



Anirudh Sivaraman
Assistant Professor, CS



Lakshminarayan Subramanian
Associate Professor, CS



Yao Wang
Professor, ECE & BioMed

NYU WIRELESS ROTATES DIRECTORSHIP: POISED FOR NEW GROWTH

(from page 3)

with New York City, Silicon Harlem, City College of New York and the University of Arizona.

Another exciting award was received by NYU WIRELESS recently from NIST (the U.S. Commerce Department's National Institute of Standards and Technology). Effort on this grant is focusing on reducing the time to bringing mmWave technology to public safety communications and is using drones as part of the project, providing an end-to-end system simulation of a complex public safety scenario. Working with the Austin Fire Department, in conjunction with the University of Padova, the investigators are using equipment

and software provided by NYU WIRELESS Industrial Affiliate sponsor **National Instruments**. Research on the three-year grant is being conducted by principal investigators Professors Sundeep Rangan and Ted Rappaport, together with Research Scientist Marco Mezzavilla and Post-Doctoral Associate Aditya Dhananjay.

With 5G becoming a commercial reality, NYU WIRELESS continues to create the state-of-the-art in wireless communications at Terahertz frequencies, along with revolutionary networks, circuits and applications — Prof. Tom Marzetta, inventor of Massive MIMO and one of the newest faculty mem-

bers at NYU WIRELESS, has been touring the world, visiting Industrial Affiliates and discussing what comes after Massive MIMO. Prof. Panwar has been investigating new networking strategies for the zero-latency era, and Prof. Rappaport recently discussed these developments with FCC Chair Ajit Pai (see page 15). NYU WIRELESS has an incredible set of talents, and an amazing board of Industrial Affiliates who provide substantial strategic and financial support.

Please join us in giving Ted our strongest support as we move toward an exciting future in wireless communications at NYU.

NYU WIRELESS WELCOMES BACK STUDENTS WITH A VISIT FROM THE DEAN

On September 5, 2018, NYU WIRELESS held a welcome back party for students and faculty for the new school year featuring presentations from NYU WIRELESS Director Ted Rappaport and the Dean of NYU Tandon, Jelena Kovačević.

Professor Rappaport's presentation focused on engaging NYU WIRELESS students, faculty, and staff members to create a "culture of collegiality, excellence, and fun."

He also outlined six exciting research thrust areas (detailed at right) that NYU WIRELESS faculty and Industrial Affiliates have identified as key research areas for the next decade. The Center is investing in these areas with research and faculty hires.

		
Channel Modeling	Mobile Edge Computing	Nano Circuits
Measurement	Caching	THz Circuits
System Design	Congestion Control	Low Power Circuits
Devices & Networks	SDN	
6G & Beyond	Fast Handover	
	Spectrum Sharing	
	Full Duplex Networking	
		
Position Location	Communication Theory	ns3
Imaging	Machine Learning	NYUSIM
E-Health	Beyond Massive MIMO	SDR
VR & AR		PAWR
Edge Computing		
Aerial Communications		
Public Safety		
Robotics/Automation		

The six research thrusts for NYU WIRELESS - all students in the center are working in these areas

FACULTY NEWS



Prof. Elza Erkip has been selected to receive the prestigious IEEE Communications Society

Communication Theory Technical Award in May 2019, "for contributions to the theory and practical design of cooperative and MIMO communications." The award is given to members of the Communication Theory Technical Committee (CTTC) of the IEEE Communications Society who have been active in the committee and have performed outstanding work.

Among the previous honors Elza has received are the NSF CAREER award and the IEEE Com-

munications Society WIE Outstanding Achievement Award. She has also been recognized for numerous highly regarded publications. Elza is currently serving as president of the IEEE Information Theory Society. Our congratulations to Elza for this well-deserved honor!



Prof. Shivendra Panwar will be giving the keynote address at mmNets, a workshop being held at Mobicom on October 29, 2018. He will also be on a panel at the workshop. Additionally, in September Shiv presented

an invited paper about the group's mmWave cellular network blockage model at the International Teletraffic Congress (ITC 30) in Vienna (itc30.org).



The Radio Club of America (RCA) announced that **Prof. Ted Rappaport** will receive the Armstrong Medal for demonstrated excellence and lasting contributions to radio arts and sciences at the annual Radio Club of America meeting in New York on November 17, 2018. He is also giving the keynote address at the banquet.

THE MMWAVE COALITION - A NEW U.S.-CENTERED GROUP

On September 27, 2018, Ted Rappaport presented "Future Wireless Technologies: mmWave, THz & Beyond." The webinar reviewed the promise and challenges of operating at millimeter wave and Terahertz frequencies. Ted discussed the current state of the art, research activities at NYU WIRELESS, and pointed to amazing new frontiers that these frequencies offer for the future of communications, computing, and imaging.

As Ted stated: "By 2020, the world will see single chip data transceivers that reliably transfer more than 10 GB/s data for more than 200 meters in a vast number of military or commercial applications." This is pushing the 5G and IoT world along as the need for massive connectivity taxes existing spectrum.

NYU WIRELESS has become the first academic institution to join the mmWave Coalition,



A slide from Ted Rappaport's welcome address to the mmWave Coalition

whose mission is to advocate for the use of radio frequencies above 95 GHz in the U.S. rural areas, ensuring that the U.S. remains competitive in the marketplace as 5G applications roll out.

The Coalition, made up of leading technology companies in addition to NYU WIRELESS, is working with U.S. and international government and regulatory bodies to eliminate hurdles to using these frequencies. Availability of this spectrum would open up much-needed broadband service for new applications for medical imaging, spectroscopy, new massively broadband IoT, and "wireless fiber" links in

The industry effort to expand the understanding and use of the frontiers of the frequency spectrum is supported by the sustaining members of the mmWave Coalition, who represent key thought leaders in the industry.

The Coalition was pleased to welcome NYU and is looking forward to more events and exchange of ideas. Learn more at mmWaveCoalition.org.

TED RAPPAPORT MEETS WITH FCC CHAIRMAN AJIT PAI



Ted Rappaport and Ajit Pai, head of FCC

Ted Rappaport recently had a one-on-one discussion with Ajit Pai, head of the Federal Communications Commission (FCC).

The agency will be auctioning mmWave spectrum this year and in 2019 to help support the rollout of 5G connectivity in the US. Rappaport and Pai discussed 5G, the state of technology in wireless, the need for mid-band

spectrum, rural bandwidth needs, and the history of 5G development.

They also touched on the leading role that NYU WIRELESS played in proving that mmWave spectrum could be used, and how directional antennas at mmWave frequencies offer better coverage than today's wireless technologies, when assuming equal area antennas.

NYU WIRELESS PARTICIPATES IN THE NGMN ALLIANCE



The NGMN alliance has worked to foster global consensus on 5G, and the ways in which system components can connect and work together

NYU Tandon School of Engineering is the only U.S.-based university that is a member of NGMN, Next Generation Mobile Networks (NGMN.org), which includes representatives from major global universities as well as CTOs from more than 20 international operators. The group's mission is to foster the advancement of communications by expanding mobile broadband, with a fo-

cus on 5G and accelerating the development of LTE-Advanced and its ecosystem. NGMN also offers guidance to equipment developers and standardization bodies.

Since the group's publication of the original NGMN White Paper in March 2015, global progress regarding 5G system developments and trials has advanced tremendously. The NGMN al-

liance has worked to foster global consensus on 5G, and the ways in which system components can connect and work together.

Their most recent public document, "Definition of the Testing Framework for the NGMN 5G TTI Interoperability," was published on September 10, 2018 and is on the NGMN web site under Publications/Technical Deliverables.

NYU WIRELESS HOSTS FIRST ITU MEETING TO ENVISION PATH TO YEAR 2030

Network 2030, a new group that is part of ITU-T (International Telecommunication Union—Telecommunication Standardization Sector), has its sights on digital networks in the year 2030 and beyond. The group was formed in July 2018, and includes members from governments, the private sector, and academia. Their first meeting was held on October 3-4, 2018, in Brooklyn and was hosted by NYU WIRELESS Professors Yong Liu and Shiv Panwar. Prior to the inaugural meeting, the first workshop also took place. Network 2030's focus is on novel technology, including holographic communications, industrial avatars, and high-precision com-



ITU-T Conference hosted by NYU WIRELESS in Brooklyn, NY

munication demands in critical situations. The group is not restricted to existing technology or networks, but will be backward compatible to support applications already developed. Network 2030 will help identify gaps and challenges as the vision for future technologies moves forward. The group's

chair is Richard Li from **Huawei**, who said, "Network 2030 is a pointer to the new horizon for the future digital society in the year 2030 and thereafter."

More information can be found at www.itu.int and clicking on Standardization or by emailing ITU-TMembership@itu.int.

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LEADERSHIP

Associate Directors Sundeep Rangan, Thomas L Marzetta, John-Ross Rizzo, and Dennis Shasha are working with Director and Founder Ted Rappaport to 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.

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