## What's Inside

THE STATE UNIVERSITY OF NEW JERSEY
RUTGERS

## WINLAB'S 10TH AND MARCONI'S 100TH PERFECT TOGETHER

What better way to celebrate WINLAB's tenth anniversary than by honoring Marconi on the hundredth anniversary of his historic radio transmission to a ship off the coast of New Jersey? And what better place to do so than at the Twin Lights in Highlands, NJ, the very location of that event?

WINLAB is proud and excited to be sponsoring "Marconi Day" on September 30, 1999, to honor a great scientist and recognize New Jersey's proud history in wireless communications. We are planning a day with "something for everyone", from distinguished speakers, to a reception and ceremonial re-enactment, to a display of antique radio equipment.

The day will begin with a series of six talks under the banner of "Wireless—yesterday, today and tomorrow". We think you will agree that this allows very broad latitude in the choice of subject matter, and we have found speakers who can meet that challenge. We thank Fumiyuki Adachi, Don Cox, Dick Frenkiel, Larry Greenstein, Bob Lucky and Andy Viterbi for agreeing to share their thoughts with us on this historic day.

Following these talks we will be whisked to the heights above Sandy Hook, for a ceremony and reception at the Twin Lights. For those of you who have not visited this New Jersey Landmark, it stands high on a hill above Sandy Hook and commands a magnificent view of the entrance to New York Harbor. We have invited dignitaries from government, industry and academe, including the Governor and the Italian Ambassador, to participate in this memorable event.

Within all these festivities, we will quietly be celebrating a second event of slightly less magnitude — the tenth anniversary of WINLAB. Our Fall Research Review and Industrial Advisory Board meeting will take place the day before, on September 29th. We are hoping that our many sponsors and alumni will return to celebrate with us, and to thank David Goodman for his ten years of leadership. We expect that this will be a "standing room only" performance and we encourage our sponsors and alumni to register early. See our website at www.winlab.rutgers.edu.

## Lucent Announces WINLAB Post-doctoral Fellowship

"In recognition of the outstanding value Lucent Technologies has derived from its ten year relationship as a sponsor of WINLAB, we present the 'Lucent Technologies Wireless Post Doctoral Fellowship Award at Rutgers WINLAB' to its Director, David Goodman." With these words, Bill Prigge, Technical Manager in Lucent's Wireless Network Group, launched a new two-year sponsorship aimed at increasing the scope of WINLAB's research agenda.

The Fellowship arose from separate but related decisions made earlier this year by Lucent and WINLAB. WINLAB was working on a plan to expand its research through Sponsored Fellowships, when Lucent Technologies' Wireless Network Group made a decision which would prove to be an important first step in that direction. In re-evaluating its University relations program, Lucent decided to focus its efforts on a small number of select schools through its University Partnership Program, and chose Rutgers University to be one of those schools.

"We have had a long history of beneficial collaboration with WINLAB," says George Zysman, VP and Chief Technical Officer of Lucent's Wireless Network Group. "The faculty is outstanding and the research is leading edge. WINLAB has proved to be

# CAREER SHIFT FOR WINLAB DIRECTOR

Marking the end of a decade and an era, Dr. David Goodman has announced that he will be leaving Rutgers for nearer-to-home (if not greener) pastures at the Polytechnic University in Brooklyn, NY. In the larger circle of life, he is returning to his hometown. For Goodman, this is an emotional returning. "I was nurtured by the public schools of New York and a New York State scholarship helped pay for my higher education. Schools like Poly are committed to educating students who otherwise couldn't afford a college education," he observed at WINLAB's Spring IAB meeting. "I was one of those students, and now it feels right to contribute to that process."

Over the years Goodman has frequently commented that his career has evolved in ten-year segments, each different and exciting, so his colleagues shouldn't have been surprised by this new direction. The problem is that ten years is also a short time, and it hardly seems possible that the founder of WINLAB has been its Director for a decade. Regaled with descriptions of his "indispensable role" in setting the vision for WINLAB, Goodman smiles his quiet smile. "WINLAB is a powerful place," he observes. "Each of us brings an individual perspective to our work, and takes away elements of a shared perspective. To the extent that my ideas are valuable in that process, they will continue to shape WINLAB's future. And because a new Director will bring new ideas to the mix, WINLAB will be that much more powerful."

Goodman's ideas have indeed shaped the wireless world, both within and outside of WINLAB. Author of more than 100 papers and several books, including three prize winning papers, he is responsible for the earliest publications on packet transmission and switching for cellular and wireless. His early work on speech signal processing is embodied in international standards. He has also traveled extensively to support the technical community as a keynote speaker, and has served as Chairman of the National Research Council committee studying the Evolution of Untethered Communications.

To his colleagues, the results of Goodman's vision are particularly obvious in the broad "systems perspective" that characterizes WINLAB. Tomasz Imielinski, chairman of the Computer Science Department and a long-term member of WINLAB, describes it this way, "The essential questions that drive research in wireless today are a natural synthesis of Computer Science and Electrical Engineering. It was the breadth of David's vision that brought us into WINLAB, and this cross-disciplinary synergy is one of WINLAB's greatest strengths. We enjoy the collaboration and it enriches our work."

In another dimension, Goodman's vision included a WINLAB that would bring together engineers from academia and industry. "It's another measure of David's unique perspective," comments Dick Frenkiel, who was invited to join WINLAB by David almost five years ago. "I wondered what role I could play in a research organization, after spending a career in systems engineering and development. David said he didn't know, but he believed something good would come of it. His willingness to experiment with research directions, organization structures and people is unique in my experience. It's embedded in the culture here. It results in a fascinating blend of academic and industrial points of view, and in projects that create new paradigms."

In the past year, Goodman had begun yet another broadening of WINLAB, this time through collaborations with other university centers including the Berkeley Wireless Research Center and the New Jersey Center for Wireless Telecommunications. Is a new collaboration between WINLAB and Brooklyn Poly in the future? "If it makes sense, technically," says Goodman. "I certainly plan to keep in touch."

# W-CDMA: WINLAB and NTT-DoCoMo "WiPPET" Up

"Every aspect of this project is a big plus for both WINLAB and our sponsor, NTT-DoCoMo" remarked Roy Yates as he reflected on the very productive first six months of a new collaboration. "The complexity of DoCoMo's W-CDMA presents a daunting task for any analytical or computational evaluation, even for the simplest models of a radio environment. That's why this project is so important. It provides a unique way to evaluate so many aspects of W-CDMA on a large scale while clearly demonstrating the power of our WiPPET multiprocessor simulation platform." This same enthusiasm was reflected in his research review talk that described the collaboration between WINLAB and DoCoMo on modeling, simulation, and multi-cell performance evaluation of the emerging W-CDMA standard.

The project was conceived during Dr. Fumiyuki Adachi's visit to WINLAB last year, and got underway in January with a week long visit from DoCoMo researcher Dr. Mamoru Sawahashi. In meeting with WINLAB professors Andy Ogielski, Narayan Mandayam and Roy Yates, Dr. Sawahashi helped to formulate the project scope, schedule, and goals. This short visit was followed by the two month stay of DoCoMo engineer Kenichi Higuchi. Kenichi worked with WINLAB graduate student Vikram Kaul to embed the existing DoCoMo W-CDMA base station simulation code in WINLAB's object oriented parallel simulator WiPPET, the Wireless Protocol and Propagation Evaluation Testbed.

Vikram's primary role was to implement a multiple transmitter/ multiple receiver asynchronous radio channel in which each transmitter offers signals (vectors) to a radio channel. The radio channel takes inputs from all transmitters and produces received signal vectors for each base station. Each base station, implementing DoCoMo's pilot symbol assisted coherent

## Sponsors Endorse Research Agenda

In the afterglow of a successful Focus '99, WINLAB received enthusiastic support for its research program at the Spring '99 Research Review and Advisory Board Meeting. Following an overview by WINLAB Director David Goodman, WINLAB faculty and graduate students gave talks on six research projects. Four of the presentations are discussed below, while the others appear as separate articles ( "Professor's Diary", page 5, and "W-CDMA,", page 2). In a survey conducted by National Science Foundation evaluator Dr. Don McCabe, WINLAB sponsors expressed unanimous support for the work presented. "It's unusual to have such a high level of support from Sponsors," says McCabe. "Other centers I evaluate don't achieve these levels. It's clear that your sponsors value your work."

### Intelligent Information Access

A vast quantity of information is arriving at our home and business terminals, and now that this information is about to pursue us through the air as well, we may be excused for wanting some help in "sorting it all out". This is the goal of professor Haym Hirsh, who described a system that can learn from a user's past email-reading habits and estimate the relative importance of new messages. The aim is to send important ones through the air to a recipient on the move with a wireless terminal and save the others for future action. Hirsh's machine-learning software lets the user balance the tradeoff between the goals of receiving everything important and economizing on the use of radio resources. He presented encouraging early results of an experiment conducted in collaboration with BellSouth Wireless Data.

### GPRS Coding Schemes

The General Packet Radio Service supports four coding schemes to help mitigate the effects of varying degrees of channel impairment. Master's Student Xiaohua Chen described how these schemes affect throughput for different channel conditions and traffic characteristics. Using the GPRS simulation

# WINLAB, A.D. (After David)*

*Jim Flanagan*
*Rutgers Vice President for Research*

People of high accomplishment are in demand everywhere, so it is never a surprise when they move on to a new challenge. For a decade we have been the happy beneficiaries of David Goodman's talents as WINLAB Director, and now we are contributing his talent to the Polytechnic University, as Chair of the Department of Electrical Engineering. It is a fitting moment to recognize the success that WINLAB has had under David's leadership.

WINLAB was founded by David in 1989, at a critical moment in wireless telephony. Cellular systems were beginning their dramatic growth, and new digital technology was emerging. The lab was created in our Department of Electrical and Computer Engineering with seed money from the State of New Jersey and a number of Industry Sponsors. This unique engineering initiative was recognized early, and in 1991 the National Science Foundation named WINLAB as one of its Industry/University Cooperative Research Centers. Since that time, it has won consistently high ranking by NSF, and its global recognition has expanded. Technologists from around the world now consider Rutgers WINLAB to be a leading institution in higher education and in research for wireless communications. It truly has become a jewel among the centers of excellence in Rutgers. (As a personal point, I have not been at all surprised by this success. I had the pleasure to be both mentor and collaborator of the Founding Director in an earlier life - and to help in appointing him to research management responsibilities in Bell Laboratories). David's leadership will be sorely missed at Rutgers, but his talent will continue to lend luster to the education and research enterprise in the new venue of Brooklyn Poly.

This is also a fitting time for Rutgers to reaffirm its appreciation for the national and international prominence to which WINLAB has ascended, and to dedicate its efforts to preserving, nurturing and growing this area of research. This focus has the full support of the university organization that spawned WINLAB - namely, the department of Electrical and Computer Engineering, the College of Engineering in which the laboratory resides, and the Rutgers central administration. It also has the support of the units that have closely collaborated with WINLAB in its industrial and government contract research, including the Department of Computer Science (DCS), the Center for Computer Aids for Industrial Productivity (CAIP), and the Center for Discrete Mathematics and Theoretical Computer Science (DIMACS).

The most significant way for all of us to show our support for this excellent Center is to find a new Director whose personal accomplishments and technical reputation can take WINLAB to new frontiers. The University is committed to this result, and we solicit the assistance of WINLAB's corporate members, its research faculty, and its many technical colleagues in this endeavor. We look forward to announcing the results of a successful search, and we look forward to the wonderful opportunity of building new research bridges with Brooklyn Poly.

tool developed at WINLAB, she has determined optimum coding schemes based on source traffic model, carrier-to-interference ratio, and channel model. She showed that the significant overhead in the GPRS data protocol influences the best choice of code, and that as packet length increases the system should switch to a more efficient code at lower carrier-to-interference levels.

### Quality of Service is a Matter of Utility

The quality of service which users will perceive in third-generation systems is heavily influenced by the expenditure of battery power and the number of bits successfully transmitted. To maximize this perceived quality, Master's student Nan Feng has created a utility function based on transmitter power and transmission rate, and has formulated

see Research on Page 5

# FOCUS '99 LOOKS AT
# "RADIO NETWORKS FOR EVERYTHING"

In one of the more ambitious agendas ever created for a conference, the WINLAB/Berkeley Focus '99 workshop took a wide-ranging look at "Radio Networks For Everything." Originally envisioned as a follow-on to the Focus '98 session on U-NII, the workshop began with the question that was so eloquently put by DeWayne Hendricks last year— "What's the killer application that will make all this happen?" Conference planners Chris Rose and Andy Ogielski decided to go where the big bucks are spent, and Focus '99 began its life as a Workshop on radio networks for the home.

Rose and Ogielski are not known for thinking small, however, and the scope of the workshop soon grew to include networks of robots and sensors, and to consider the implications of conflicting standards in the same environment. It even grew to encompass the "human perspective," in the form of Steve Mann and his "wearable computer". The final result of their work was a program that covered the entire range of communications topics, from the human atop the stack, to applications, to networks, to systems and hardware design for transceivers.

At the transceiver level, Bob Broderson of UC Berkeley talked about the "universal radios" which would actually make feasible the concept of "radio networks for everything." He described how silicon technology would provide the cheap and fast radios that could drive the technology for such ubiquitous radio networks.

Transceiver system-level issues were discussed by Chris Rose of WINLAB, Sergio Verdu of Princeton University and Greg Pottie of UCLA. Verdu reflected on trends in wireless multiuser communications which are primarily based on receiver enhancement, while Rose provided a different (but conceptually similar) view that transmitters could be the focus of enhancement via a technique he calls interference avoidance. Pottie pointed out the value of distributed sensor networks that would essentially coordinate information from remote transceivers and act as a mechanism for realizing "radio networks for everything".

At the network level, Mario Gerla of UCLA proposed wireless mobile ad-hoc networking algorithms that could support the concept of ubiquitous wireless networks. Deborah Estrin of USC reviewed the lessons learned from the Internet about scalability and suggested that these be reevaluated in the world of mobile networks.

In addition to offering individual presentations on Home RF and BlueTooth, Jim Lansford of Intel and Jaap Haartsen of Ericsson joined Subrata Banerjee of Phillips and Keith Thompson of SUN in an exciting panel discussion that contrasted these standards. There were also talks on experimental testbeds from Anthony Joseph of UC Berkeley and Jason Redi of BBN. Joseph discussed the Berkeley activity on merging wired and wireless IP networks, while Redi presented interesting demonstrations regarding wireless networking for robots. Luis Sanchez of BBN pointed out issues in wireless network security that must be addressed for such ubiquitous networks to be commercially useful. Jim Evans of WINLAB presented an exciting view of the novel applications possible with Backscatter radios that could be built for less than a dollar. A wrap-up session led by Tomasz Imielinski of WINLAB included Redi, Sanchez, Joseph, Chris Lewis of Sandia and Gary Kelson of Berkeley.

The "double-duty" award goes to Steve Mann of the University of Toronto, who was both a session speaker and a dinner speaker par excellence. Mann discussed his humorous and frequently poignant experiences with a "wearable computer" mediating his view of the world. It is a world in which the human and computer are intimately connected, and where radio networks are truly embedded in our lives.

Focus '99 played out to a crowd that frequently threatened to overflow the room, and if some of the questions it posed remained unanswered, no one seemed disappointed. In the words of an attendee, "I enjoy these sessions because the questions are so broad and interesting. If they were easy it wouldn't be any fun."

For early planners, the Berkeley/WINLAB Focus 2000 will take place on the "other coast" at approximately the same time next year. Based on past experience, it will be characterized by great speakers and will raise as many questions as it answers.



20 Years in the evolution of Mann's "WearComp" (Wearable Computer) and "EyeTap" Video Inventions from the late 1970's (left) to the present (right).

a non-cooperative game in which each mobile station attempts to maximize its own "utility". Feng presented results from her single cell CDMA simulation, which demonstrate the influence on utility of power, system load, and distance between transmitter and receiver. She then compared the equilibrium power and utility for different modulation techniques. She demonstrated that for each modulation technique there exists an optimum packet length, based on utility. Finally, she discussed extensions to a multi-cell CDMA system with joint power and rate control.

### A Single 3G Standard is Hard, so Radios Should be Soft

The number of standards proposed for third-generation (3G) wireless-systems suggests the need for an unprecedented degree of flexibility, both to support multi-media services and to optimize system performance. The requirements of maximum speed and flexibility at an affordable price call for a unique architectural approach starting at the physical layer. WINLAB researcher Ivan Seskar described his work on a Software Defined Radio that can handle the processing speeds required of 3G radio receivers. The approach is based on an architecture that partitions receiver-processing implementation into two core technologies: field programmable gate arrays and digital signal processors. Using this approach, researchers have implemented advanced receiver algorithms, including nonlinear interference cancellation and linear multi-user detection.

a good investment for us, and we believe that this expansion of our support will benefit both organizations."

When Zysman and Prigge met with WINLAB's David Goodman and Phil DiPiazza to discuss how the increased Lucent support should be focused, the Fellowship quickly emerged as the winner. "We see these sponsored Fellowships as a benefit to everyone," says Zysman. "They will attract the best researchers to WINLAB and strengthen the ties between WINLAB and its Sponsors. We decided to sponsor a Post-Doctoral Fellowship because we felt that a post-doc would add most significantly to WINLAB's total research program."

## A Professor's Diary
### Carpooling on the Internet
### by B.R. (Badri) Badrinath

I keep discovering that the worlds of wireless and the Internet interact, and pull each other in interesting new directions. This was demonstrated once again in work I was doing with Ph.D. student Pradeep Sudame on protocol adaptation for wireless. We were struck by the inefficiency of our existing protocols for small packets, and Pradeep decided to design a "transformer tunnel" which would combine these packets before transmission.

Our wireless studies never take us far from the Internet, where bottlenecks are common and the performance is sometimes characterized as the "world wide wait." Since Internet traffic is also dominated by small packets, we realized that our approach for wireless might apply there also. We realized immediately that a catchy name was essential, but "packet aggregation" and similar candidates were rejected as dull and nerdy. Then the image of a "carpool" for packets popped into my mind, and "carpooling on the Internet" was born.

Packet processing overheads such as route look-ups, interrupt processing, wireless- and wired-channel access and link layer overhead cost the same irrespective of the size of the packet. Similarly, the congestion seen on the Internet is directly related to the number of packets in the network. Hence, "packet reduction technology" improves the overall performance and level of congestion seen by packet-limited routers.

With this in mind, we introduced an architecture in which "aggregators" combine small packets that have a common (intermediate) destination, and "splitters" separate them for delivery to their final destinations. These aggregators and splitters can be attached to any router, and their placement has an important impact on the overall performance of the network. Dealing with these architectural issues and side-effects of "carpooling" promises to be interesting research with potentially important performance benefits for busy Web servers, TCP networks with asymmetric links, and for "chatty" protocols. Once again the "wireless connection" has led to a new direction in Computer Science!

## CARTOON CORNER
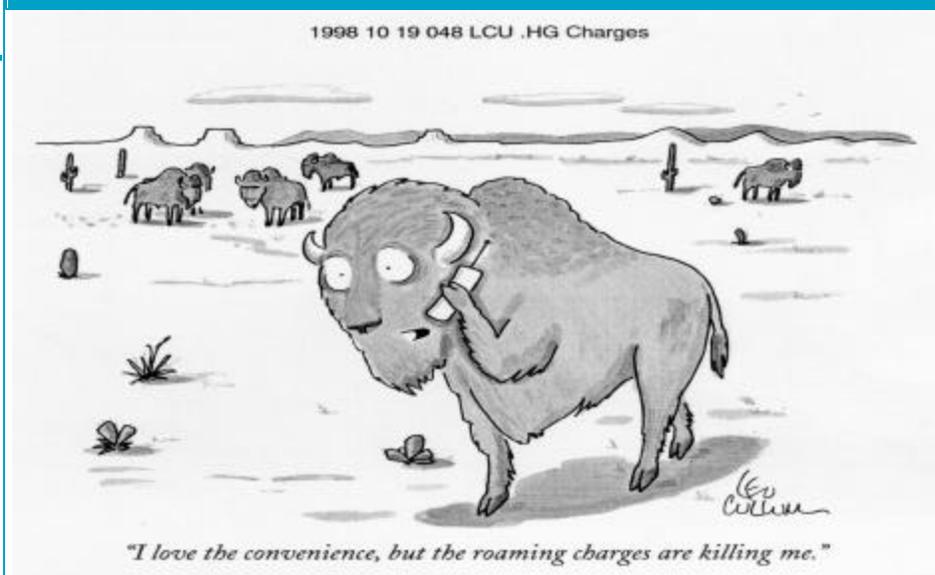


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"I love the convenience, but the roaming charges are killing me."

multistage interference canceler, processes these received signal vectors to decode transmitted bits. An extensive effort has been completed to verify that the WINLAB/DoCoMo simulator duplicates DoCoMo's existing single base station simulation results. With the recent implementation of slot by slot SIR estimation and power control feedback, a thorough evaluation of the DoCoMo receiver in a multicell system is now underway.

"We believe this effort is the first one of its kind. The results will enable us to understand the impact of interference cancellation in a multiple cell system with mobile users," says Mandayam. "Previous results always make simplifying assumptions which raise questions regarding the feasibility of such receivers in real systems."

This multicell W-CDMA physical layer simulation technology is expected to be a platform for new directions in WINLAB research. "We think the WiPPET radio channel simulation can be adapted to other technologies such as EDGE," says Yates. A second direction is towards the Internet.

WiPPET is one part of the multi-university parallel network simulation project known as SSFNET. (See the webpage at http://www.ssfnet.org) Under the leadership of Andy Ogielski, SSFNET has built a large scale parallel simulation of the Internet. "Next we'll embed the WINLAB/DoCoMo simulator as physical and link layers in SSFNET," says Ogielski. "Then we'll have the first large scale, multi-protocol 3G wireless Internet simulation."

## WINSPEAK

Congratulations to David Goodman who won the 1999 RCR Gold Award at the 1999 IMT-2000 3G Wireless Technology Conference. The winning speech was entitled, "Meeting the Challenges of Wireless Communications". Welcome to our newest sponsor, SBC Technology Resources. We look forward to a productive relationship.

On February 22, 1999, more than fifty members of the wireless communications industry convened at Rutgers for a Workshop on the General Packet Radio System (GPRS), held under the auspices of the New Jersey Center for Wireless Telecommunications. The Workshop consisted of presentations from industry (Ericsson Radio Systems, AT&T Labs, Lucent Technologies, Nortel Networks), presentations by WINLAB faculty and students, and a panel on the need for ongoing University research.

Congratulations to all of the WINLAB students who graduated this year!! Pi-Chun Chen has defended her Ph.D. thesis, "Mobile Position Location Estimation in Cellular Systems," and is now employed at Telcordia. David Pandian has defended his Master's Thesis; "Channel Allocation and Power Control in IS-136," and is now at Qualcomm. After defending her Master's thesis; "Utility Maximization for Wireless Data Based on Power and Rate Control," Nan Fang will work on her Ph.D. at WINLAB.

Congratulations also to graduates David Famolari, Kamesh Medepalli and Shalinee Kishore,. David is now at Telcordia, while Kamesh is at Lucent Technologies and Shalinee is at Princeton University.

## WINLAB
**WIRELESS INFORMATION NETWORK LABORATORY**

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