



PACKETS

FOCUS '99 **On** **Radio Networks for** **Homes and** **Small Businesses**

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THE STATE UNIVERSITY OF NEW JERSEY
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WINLAB APPOINTS NEW TECHNICAL DIRECTOR

WINLAB has announced the appointment of Dr. Philip S. DiPiazza as its new Technical Director. In that role, Phil will be working closely with WINLAB Sponsors to assure that they get the maximum benefit from the many research projects that are currently underway and to shape new directions for WINLAB research.

DiPiazza comes to WINLAB with broad industrial experience. The first decade of his career was spent in creating radar systems. In 1976, he joined the AMPS cellular project at Bell Labs, helping to shape the system architecture and refine its algorithms and protocols. Ultimately he led the team that tested the first AMPS system in Chicago, and pronounced it ready for commercial service in 1983.



"That was quite a moment," he reflects from his new desk at WINLAB. "We had cell sites designed in Whippany, New Jersey, a switch designed in Naperville, Illinois, and mobile units designed in half a dozen places around the world. The fact that it all worked was a source of wonderment to us all."

Dr. Franklin H. Blecher, who was the project leader for AMPS, has an explanation for this rare phenomenon. "The AMPS project had the benefit of some great systems engineering by people like Phil," he said in a telephone interview. "I believe that was the underlying key to our success."

Phil is too modest to claim credit for this achievement, but from the AMPS project he took away a deep appreciation for the value of systems engineering, and an eagerness to teach in this

area. He was a guest lecturer in Dick Frenkiel's course "Systems Engineering and the Creation of Large Wireless Systems", and is eager to expand on that experience. Since Phil and Dick worked together on the AMPS system, we look forward to their renewed collaboration.

Phil went on to a variety of projects at Bell Labs (PCs, touch screens, and fax) before returning to radio, this time in the form of a new "cordless business telephone system" for the 900 MHz ISM band. Phil retired from AT&T in 1998 and returned to his systems engineering roots, this time as a strategic consultant.

"I think that Phil brings a valuable new dimension to our capabilities," says WINLAB Director David Goodman. "We have crossed paths many times in our careers, and I was

always impressed by his wide experience and insight, and by the tremendous enthusiasm he brings to his work."

That enthusiasm was evident when we asked Phil how he liked his new role. "I think I died and went to heaven," was his instantaneous answer. "This is what I've always dreamed of doing". And does he have an immediate goal? "Well, I'd kind of like a permanent desk, and maybe even a telephone— so I can start to call our Sponsors."

**WINLAB Sponsors One-Day
Seminar on GPRS**

February 22, 1999

**See Page 5 for details or visit
our website at
www.winlab.rutgers.edu**

SPONSORS SAMPLE WINLAB WORK

In the centerpiece of WINLAB's Fall 1998 Research Review, students and professors presented a sampling of the many research projects currently underway. The Review began with an overview by WINLAB director David Goodman that compared the WINLAB of today with the WINLAB of a decade earlier. Goodman observes that wireless voice services are achieving the "anytime, anywhere" availability that was the dream of that earlier time, and now wireless data is struggling to follow a similar path. He described the limitations that stand in the way, and how WINLAB is addressing those limitations. For the details of this provocative view, see the front page of the last Packets (October 1998).

Following his overview, David presided over the presentations of seven projects by students, professors and a recent Ph.D. graduate. Using the National Science Foundation feedback forms, Sponsors gave the presentations high marks for relevance, and a strong vote to continue and expand this work. The following paragraphs, along with an accompanying article by Professor Chris Rose (Professor's Diary, Page 4)

summarize the project presentations.

Student Learns the Value of the Dollar

In the first student presentation, Master's student David Famolari discussed error correction and power control based on utility and "pricing". Continuing on a path described by Pascalis Ligdas in the previous Review, this work applies microeconomics to the problem of power control for wireless data.

Famolari seeks to maximize the amount of information users can transmit in the limited lifetime of their batteries. He showed that everyone could send more information if they would all lower their transmitter powers relative to the optimum levels for voice communications. He went on to show that introducing a "pricing" function to the power control algorithm could promote this efficiency in a distributed, non-cooperative situation. Those in the audience who don't like complicated communications services bills were glad to find that "price" is a parameter of the algorithm, and that the gains are achieved

without charging for each bit.

Work on Level Crossing Extended

At earlier Reviews, WINLAB researchers introduced a theory of level crossings that offers a useful and intuitive model of a fading channel. Using this model, Ph.D. candidate Jie Lai described a study of the performance of non-interleaved Reed-Solomon (RS) codes on narrowband channels. The approach is quite general, and can be applied to any class of block codes. The new approach allows the influences of fade margin, Doppler frequency, and error-correction capability to be studied directly. In future work, this powerful approach will be applied to wideband channels and to systems with interleaving.

A Proposal for Interference Cancellation and Equalization

An active area of research in many laboratories is the application of interference cancellation and equalization to enhance the uplink performance of highspeed data channels. Achieving similar improvements for the downlink poses a formidable problem, since the terminal design is constrained by more stringent limitations on cost, complexity and battery power. Master's student Kamesh Medepalli described a simple but effective approach to combat co-channel and inter-symbol interference in TDMA cellular systems. It involves a three-stage receiver, and relies on interference cancellation and equalization using tentative decisions. Using Medepalli's approach the receiver cancels desired symbols using a tentative estimate of the transmitted signal. This makes it possible for the receiver to estimate, and then cancel the interference. The procedure produces significant improvements when the signal-to-interference ratio is low, especially when the channel memory is small.

Access Control for Multimedia CDMA

As multimedia services with variable Quality of [\(continued on next page\)](#)

CARTOON CORNER



"Get me Room Service."

Service (QoS) requirements become available in the “wired” world, there is a need for efficient mapping of these QoS requirements into wireless environments. Access control protocols described by Ph.D. candidate Cristina Comaniciu take into account the complementary QoS requirements of voice and data, and schedule the data users to transmit more packets in periods of low voice activity. The residual capacity available for data users is predicted using a technique that is reminiscent of delta modulation for analog-to-digital conversion. Comaniciu’s algorithms guarantee a low probability of outage, a specified average throughput and a guaranteed minimum throughput for data users, while maximizing system capacity.

Pulling the Cork on the New Bottleneck

Just as Infostations create all the low-cost high-speed radio capability we could ever want for wireless data, we find a new bottleneck—the “wired” backbone that connects it all. This results in part from the possibility that Infostations will be connected to low-speed links for economic reasons, and in part from our uncertainty as to where the mobile will next appear. Because of this uncertainty, moving the files for many users to multiple locations can result in heavy loads on the backbone network.

With the goal of minimizing total delay, Ph.D. candidate Ana Iacono has begun to study this problem, and presented initial results for a linear “highway model”, in which the system must send parts of a large file through a slow backbone to multiple Infostations. Ms. Iacono presented an algorithm for file delivery along with simulation results that indicate that the algorithm achieves near-optimum delay. She is expanding this work to more complex network configurations.

Optimizing CDMA Transmitter Codes

For single cell CDMA systems, optimal signature sequences are those that minimize the sum of the squared correlations. If the number of users is no more than the processing gain, then orthogonal signatures are opti-

mal; otherwise, signatures which satisfy the Welch bound on the total squared correlation with equality are optimal. The basic idea in such cases is to update one signature sequence at a time to reduce the total squared correlation, and there are many ways to accomplish this.

Recent WINLAB Ph.D. graduate Sennur Ulukus has created such an algorithm. At each step, it replaces one signature from the set with the optimum linear receiver filter corresponding to that signature. This procedure is amenable to distributed implementation in which each transmitter-receiver pair updates its own signature sequence by making local measurements and the whole signature sequence set converges to an optimum that maximizes system capacity.

Deploying Service Across Multiple Systems

Did a fax arrive on your home server while you were on your way to a meeting? Never fear — using the service architectures described by WINLAB professor B. R. Badrinath, you’ll hear about it over your pager and download it at the next Infostation. The availability of a wide variety of networks (such as the telephone network, the Internet, paging networks, cellular networks, wireless data networks, and Infostations) presents new challenges for deploying services, and Badrinath is beginning to explore the possibilities. Providing

services over these cascaded networks, where any service can be requested over any network, requires new support protocols and service decomposition. Dramatic differences in bandwidth and availability must be addressed so that the overall service will be presented in a consistent and logical way. The architecture calls for programmability of network functions to handle user needs, network characteristics, input-output modalities, and spatial and temporal preferences for a given network.

WINSPEAK

WINLAB looks forward to mutually rewarding collaborations with our two newest sponsors, Sprint Corporation and DaimlerChrysler. Congratulations to three new Master’s graduates. Shalinee Kishore defended her thesis, “Scheduling Multirate CDMA Users Based on Average Power Consumption”. David Famolari’s topic was “Parameter Optimization of CDMA Data Systems” and Kamesh Medapalli presented “TDMA Interference Cancellation and Equalization Using Tentative Decisions”. We are happy to acknowledge the stimulating seminar presentations of Mamoru Sawahashi of NTT on Wideband DS-CDMA, Peter Schefczik of Lucent on GPRS, Jaap Haartsen of Ericsson on Bluetooth, and Manish Mangal of Sprint on Multi-User, Multi-Rate QoS of DS-CDMA.



Eugene Famolari, center, Associate Technical Director, US Army CECOM Research, presented the dinner talk at the Fall Research Review. Prior to the talk he exchanged views with Professor Andy Ogielski of WINLAB and Dr. Prathima Agrawal, Bellcore Chief Scientist.

Sponsors Endorse New Initiatives

In a particularly lively meeting of the Industrial Advisory Board (IAB), WINLAB sponsors, staff, and visitors worked together to map the course of four new WINLAB programs. Two of them are long-term collaborations with other universities and two are public meetings designed to set research agendas in emerging fields. Professor Sirin Tekinay of the New Jersey Institute of Technology introduced the first collaboration, a four-university Center for Wireless Telecommunications in New Jersey (See page 5).

Dr. Gary Kelson, Technical Director of the new Berkeley Center for Wireless Research at the University of California, introduced the second collaboration. Gary presented his Center's exciting vision of a new generation of low-power radios on a silicon chip. David Goodman explained how WINLAB's expertise in protocols and algorithms would provide a systems context for the new radios.

In addition to conducting joint research, the WINLAB and Berkeley Centers will collaborate in an annual series of public workshops that began with Focus 98 on U-NII (Packets, October 1998). WINLAB Professor Andy Ogielski led the (IAB) discussion on themes for Focus 99. The initial suggestion, "Home RF", expanded into the larger theme "Radio Networks for Homes and Small Businesses". The Focus 99 workshop will be held in New Brunswick, New Jersey on May 24-25, 1999.

The final topic, General Packet Radio Service (GPRS), also provoked a lively discussion. GPRS is a new wireless packet data standard to be integrated with GSM Services. WINLAB's pioneering research on GPRS performance has attracted a lot of attention throughout the wireless communications community, and David Goodman asked for input on how to plan future research that will provide maximum benefit to Sponsors. In response, the IAB suggested that WINLAB host a meeting of experts to assess current knowledge of GPRS and guide future research. An announcement of the WINLAB Seminar on GPRS, to take place at Rutgers on February 22, 1999, appears on Page 5.

PROFESSOR'S DIARY

A walk in the garden with Chris Rose

Roy Yates and I have always been close collaborators, so it was not surprising that recently we found ourselves digging happily in the same garden (to those of you who don't think that multi-user wireless communications channels is a garden, you can pick up your shovels and be gone. We poet-engineers know a good metaphor when we dig one up.) Anyway, what was pleasing about this was that we had wandered into this garden from different directions, only to discover the same flower. As the discoverers, we have named it interference avoidance (*interferens avoidens* for those in horticultural circles.)

For me, the path began with an interest in ISM band systems (a path suggested by Roy, before he wandered off in new directions). At first look, these bands are so chaotic as to defy logical analysis, but some of us are quixotic enough to enjoy hopeless tasks. Then the FCC released 300 MHz of unlicensed spectrum in the 5GHz "U-NII" band, the topic of WINLAB's Focus 98 workshop. For services in the U-NII band, peaceful coexistence among interfering transmitters is essential. I was still confused, but at least I knew the research was relevant.

As is often the case when you don't know where to start and there is no relevant literature from which to work, you go back 25 or 50 or 100 years and steal from the past. In this case, it was the whitening theory developed for radar systems that suggested a solution— simply measure the interference characteristics (the autocovariance function) and design a receiver which suppresses the interference (a whitening filter).

Having suppressed the interference in reception, it became clear that still better performance could be achieved if one could also adapt the transmitted signal to the current interference environment. Since this path led into the interesting world of "universal" or "software" radios, I began to enjoy the scenery. Still, there was the problem of how an ensemble of "waveform-agile" users would behave, and it was here that I once again bumped into Roy.

Roy, having done some landmark work in power control, was looking at Sergio Verdu's intellectual child, multi-user detection, with an initial eye toward fitting power control into the overall picture. Upon hearing about my problem, he described his work with Sennur Ulukus on synchronous CDMA systems. Using optimal filter coefficients derived from the interference, the transmitter could create a waveform that both gave and encountered less interference.

Emboldened by Roy's and Sennur's success, I pushed immediately forward on the whitening approach and found that the greedy method (in which each user simply chooses the signature which provides the best "personal" performance) converged for ensembles of users. Moreover, I found that "poor" users (in the world of signal level) could force rich users to more equitably share the medium (a most satisfying result for the closet revolutionaries among us). And finally, the whitening method assumes little about signal structure and therefore the method is extremely general.

As of this writing, Roy and I have compared notes and have begun to formulate a general class of interference avoidance algorithms. We are therefore extremely excited by the prospect of collaborating with the Berkeley Wireless Communications Center, because their special expertise is universal radios. Issues of complexity and stability may, for the time being, confine the new interference avoidance techniques to fixed (as opposed to mobile) wireless systems, but it's fertile ground and Roy and I intend to dig here for a while.



New Jersey Launches Wireless Excellence Center

Recognizing the strategic importance of wireless communications to the State's economy, the New Jersey government has established a new Center for Wireless Telecommunications. The NJCWT unites WINLAB researchers with colleagues at New Jersey Institute of Technology, Princeton University and Stevens Institute of Technology. The Center will be launched on January 1, 1999, with funding from the New Jersey Commission on Science and Technology of \$1.1 million for the initial year of operation. The Commission anticipates a five-year funding program for the new Center.

The Center has formed research teams in four major areas: propagation, radio frequency engineering, wireless networking, and applications. A major theme of WINLAB's participation focuses on Infostations. Present funding for Infostations projects comes from the military sector (Defense Advanced Research Projects Agency). The New Jersey Center will provide an opportunity to expand WINLAB research in promising areas, such as Infostation applications for the commercial sector. Such applications could include "Mom and Pop" Infostations, operated by small business for the purpose of disseminating locally relevant information as well as handling the messaging needs of passersby. Dick Frenkiel, David Goodman and Chris Rose look forward to working with Stevens colleagues who already have made considerable progress in their "InfoCity" project, which targets the information needs of people in fixed locations.

All four Universities have conducted research in the past on multi-user detection of wireless signals and radio resource management. Roy Yates and Narayan Mandayam will play a major role in bringing WINLAB expertise in these areas to the rf engineering efforts of the new Center.

David Goodman comments that the State of New Jersey funding for

WINLAB's participation in the Center at the level of about \$250,000 per year adds considerable leverage to Sponsor investments in WINLAB research. According to David, "This is truly a win-win situation. The Center begins with a lot of momentum, thanks to high levels of Federal and

private support at the four Universities. The sponsors of the ongoing research will benefit from the increased level of activity and the synergistic collaborations fostered by the Center."

Information on the new Center is available at www.njcw.org.

WINLAB Collaborates in a Study of Collaboration

Collaboration is the hallmark of human activity, and with globalization a major theme of modern life, never before have people collaborated over such great distances and in such varied environments. With this increased scope have come visions of new and richer forms of electronic collaboration. We routinely share and edit documents over global networks, and the idea that doctors in different countries might collaborate in a diagnosis is no longer surprising. But imagine a scientific discussion among people in different locations. They would want to share the same information in its many forms, and discuss it with knowledge of who is speaking, or pointing at an image, or writing on a white board visible to all, and they would want changing information to be updated in all locations. In emergency situations, the need for collaborations among distributed participants in diverse environments is even more complex and dramatic.

To make this possible, the National Science Foundation (NSF) has awarded a three-year, \$2.2 Million grant to a team of Rutgers researchers headed by Dr. James Flanagan, Director of the Center for Computer Aids to Industrial Productivity (CAIP) and a recent winner of the National Medal of Science. The grant is part of the NSF's program on Knowledge and Distributed Intelligence (KDI) in the Information Age. The goal of the research is to establish and demonstrate a system for multi-user collaboration across heterogeneous computing environments. Mobility and wireless systems will be a common characteristic of these environments, so it is not surprising that WINLAB's David Goodman and Narayan Mandayam are members of the team. Their task is to unite WINLAB's work on mobile multimedia communications with CAIP's research on collaborative computing.

"NSF's cultivation of this highly multidisciplinary research arena," said NSF Director Rita Colwell, "will change the way scientists collaborate and the way they prepare to examine the world as they seek new frontiers for discovery."

ONE-DAY WINLAB SEMINAR ON GPRS

Responding to a mandate from its industrial Sponsors, WINLAB will hold a one-day seminar on February 22, 1999 on the new General Packet Radio Service (GRPS). Experts are invited to learn the latest results of WINLAB research, exchange views, and set a research agenda for the future. The seminar will consist of a mixture of presentations and discussions.

We welcome presentations of research results and accounts of work in progress. If you would like to speak at the seminar, please send the title and a brief summary of your presentation to:

Dr. Philip DiPiazza (phild@winlab.rutgers.edu).

If you would like to attend, please contact:

Melissa Gelfman (gelfman@winlab.rutgers.edu).

There will be a nominal registration fee of \$100 to cover our expenses. Further information is available at www.winlab.rutgers.edu.



WINLAB Professor Receives NSF Career Award

Professor Narayan Mandayam's first three years at WINLAB have been exceptionally eventful and productive. He has been at the heart of a wide range of original research projects and novel educational initiatives. Recognizing his achievements to date and his bright prospects, the National Science Foundation has recently announced that Narayan will receive a prestigious NSF Career Award. Career awards provide recognition and funding to the leading young researchers at American universities and are one of the highest honors given to young faculty members. Narayan's award will support his adventurous research in microeconomic theories for radio resource management in wireless data networks, a topic that fits perfectly with WINLAB's current research focus.

Narayan arrived at WINLAB in September of 1994 as a Postdoctoral Fellow after earning his Ph.D. at Rice University. When he finished his Postdoctoral Fellowship in 1996, he wanted to continue his association with WINLAB "because of the superior research environment and interaction with other professionals of international repute". Happily, the feeling was mutual. Narayan was awarded a tenure track faculty position in the Department of Electrical and Computer Engineering at Rutgers and became a permanent member of the WINLAB team.

Narayan's individual and collaborative efforts have been very productive. His initial work with Jack Holtzman on capacity and protocols for integrated voice/data Code Division Multiple Access (CDMA) systems was funded by the NSF, and the Office of Naval Research has awarded him a grant to implement a testbed for CDMA multi-user detection. He is also involved in two other NSF grants awarded to WINLAB. One is in collaboration with the University of

California, San Diego relating to multi-user detection, while the other is with David Goodman concerning multi-modal collaboration across wired and wireless networks.

Next semester, Narayan will introduce a new course, Advanced Topics in Communications Engineering. This new graduate course in wireless communications will cover link-level issues in both narrowband and wideband wireless communications systems. When asked how he sees his future at WINLAB Narayan says, "I just want to continue to be a part of the new frontier of wireless research in communications." And when pressed for a slightly less global objective, he answers with that engaging smile. "Well, there's this tenure thing"

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