Wireless and Broadband Technologies

1. Introduction

Advances in communication, device, and processor technologies have led to the creation of a wide range of information devices: tiny wearable computers, ultralight laptops, personal digital assistants (PDAs) and cellphones, desktop computers and high-end servers. These advances have made internet a household word, given every American access to the treasures in the Library of Congress, enabled applications such as e-commerce and forever changed our everyday lives. Future demands in voice, video, and data transmission, coupled with the mobility of our society, mandate the development of wireless and broadband networks. Advances in these technologies will enhance the quality of communication through improved access, speed, and connectivity, enhance the quality of information technology applications, and make possible distance interaction in a realistic environment (e.g., distance learning and virtual reality).

LSU has the opportunity and the foundation on which to build a center of excellence in wireless and broadband technology that will serve the educational and development needs of the state and carry out nationally competitive research. This initiative is rooted in the Master Plan for Economic Development, Louisiana: Vision 2020, which has identified the Internet and telecommunications as components of a technology cluster targeted for development in the diversification of Louisiana's economy. The thrust is also in line with the goals of federal agencies promoting the information technology for the twenty-first century (IT^2) initiative.

This initiative, based on current strengths and perceived potential of reaching national prominence, proposes an integrated effort to address issues that push the state-of-the-art of wireless and broadband technologies. Figure 1 shows the relationships among the component areas of the proposed research. Networking focuses on means for a collection of computing and information devices to work together effectively. The wireless and broadband initiative involves all aspects of communications dealing with tetherless access (wireless) of information, and high-speed information transfer (broadband). Though the two terms are not mutually exclusive, wireless is normally associated with lower frequencies (RF) while broadband is associated with higher frequencies (optical). Advances in wireless and broadband access depend on hardware developments in microelectronics, photonics, RF integrated circuits, and low-power design. The proposal is organized according to these topics.

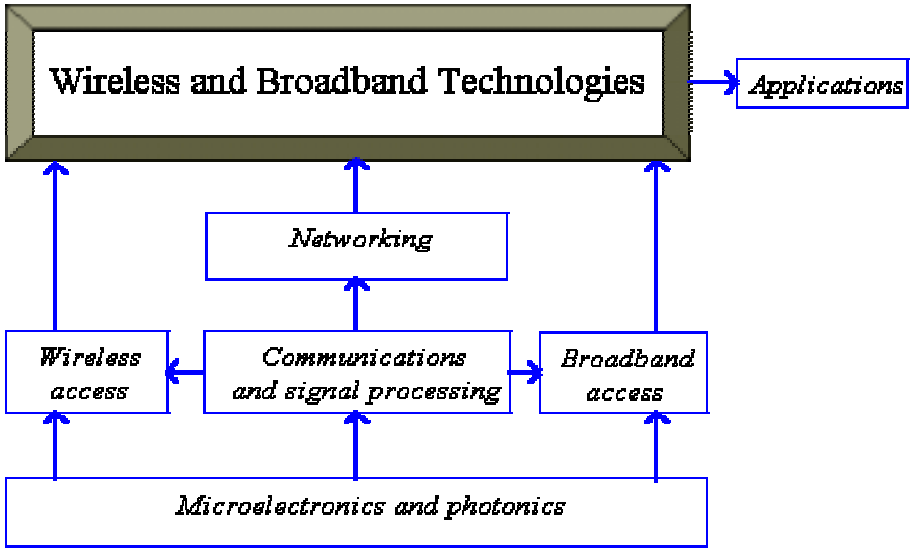

Figure 1. Major components of wireless and broadband technologies

2. Wireless Communication

Research and teaching in wireless communication will encompass all aspects of wireless communication systems including physical layer, multiple access protocols, local area networks, personal communication systems, and ad-hoc networks. This area will require four new faculty positions.

With the advent of new technologies such as personal communication systems, local multipoint distribution systems and Bluetooth, different aspects of radio propagation need to be modeled, analyzed and measured. To cope with the limited available spectrum and to combat the high and fluctuating error rates in the radio channel caused by mulitpath fading, efficient modulation and error control strategies are required. Channel equalization, spread spectrum and multiuser detection are also required to mitigate the disruptive effects of the radio channel on the transmitted signal. Development of smart antenna arrays will increase the capacity of the network allowing more users to access the network services. With ever increasing demand on the radio spectrum, efficient multiple access protocols must be designed to enable users to share the limited spectrum. Furthermore, as multimedia services are being moved to the wireless environment, support of differentiated quality of service in the multiple access protocol becomes essential. Mobile ad-hoc and self-reconfigurable wireless networks have become important research topics. In many applications such as emergency management response and tactical battlefield where a central base station cannot be easily deployed, these networks can be deployed quickly and effectively. Software radio is an emerging technology in which the channel modulation waveforms are defined in software allowing simple implementation of multimode and multiband radios. Finally, system architecture issues need to be investigated.

- **Radio Propagation**: Measurement, modeling and simulation of propagation effects in the radio channel for mobile, personal, broadcasting, and fixed applications.
- **Modulation and Coding**: Design and analysis of power and bandwidth efficient modulation and error control strategies particularly for broadband wireless applications.
- **Data Compression**: Development of efficient data compression schemes for multimedia sources.
- **Signal Processing**: Analysis and implementation of signal processing algorithms for channel equalization, spread spectrum modulation, and multi-user detection.
- **Smart Antennae**: Development of smart antenna arrays to increase capacity and performance of wireless systems through spatial diversity.
- **Multiple Access**: Multiple-access protocols for differentiated quality of service support in wireless local area networks and the next generation of integrated personal communication systems, digital subscriber line systems and high speed wireless access for broadband.
- **Mobile Ad-Hoc Networks**: Multiple-access and routing protocols for differentiated quality of service support in mobile ad-hoc and self-reconfigurable networks.
- **Software Radio**: Software radio solutions for the next generation of personal communication systems.
- **System Architecture Issues**: System design issues for different features and characteristics. Wireless local area networks, personal communication systems, local and multi-channel multipoint distributed systems.

3. Broadband Networking

Research and teaching in broadband networks will address key innovative concepts in the next generation of high-speed networks, including switching and routing, emerging protocols, interoperability between wireline and wireless networks, optical networking, and security and management. This area will require three new faculty positions.

To address the mismatch between the speed of optical transmission systems and the electronic processing, new switching and routing paradigms are required. Quality of service (QoS) will be a key feature in the deployment of next generation networks. The inherent conflict created by the need to optimize bandwidth while ensuring different QoS can be resolved by using a combination of traffic management techniques. With the advent of multi-protocol label switching technology, traffic engineering allows service providers to distribute the traffic load away from congested parts of their networks and onto the less congested parts in a dynamic way, better maintain their service level agreements, and deliver differentiated quality of service. With sensitive information (e.g., e-commerce, Internet shopping, and banking) being transmitted over the public network security has become critical. This will be an important subject of research in the next generation networks. Interoperability of wireless and wireline networks (i.e. converged services) must be addressed. Virtual private networks would allow enterprise to share the public Internet with privacy, security and service guarantees equivalent to that of a private network. Network security and management are relevant to both

wireless and broadband as they not only apply to performance and security management but also to accounting and billing systems. Further, the research and teaching in optical networking is of paramount importance to broadband technology.

- **Switching and Routing**: Switching architectures, scheduling, quality of service, scalability, control and data plane separation, meshed and optical backplanes, integration of routers with RF.
- **QoS and Traffic Engineering**: Integrated services (IntServ), Differentiated Services (DiffServ), policing, shaping, resource allocation, fault detection and path recovery.
- **Protocols**: Multiprotocol label switching (MPLS), network based virtual private networks, IPSec, packet cable, resilient packet rings.
- **Converged Services**: Wired and wireless interworking, TCP/IP in wireless environment, wireless ATM, Internet telephony.
- **Security and Management:** Encryption, authentication, key distribution, third party certification, processor architecture for line-rate processing, firewall, MIB, mobility management.
- **Optical Networking**: Dense Wavelength Division Multiplexing, all-optical network architectures (for LAN, MAN, and WAN), all-optical switching, wavelength converter placement, capacity utilization, add/drop networks, performance monitoring.

Appendix A lists the equipment for the wireless communication and broadband networking initiative.

4. Enabling Technologies

The generation, processing, transmission and receiving of signals that carry information require systems and hardware. Technologies that make possible the hardware necessary for implementation of IT come under the umbrella of enabling technologies. Technology for computer processors and memory, wireless and broadband transmission, optical switching, photonic devices and processing and newer device and circuit concepts that push the state of the art are also included under this area. Select areas in which the department has potential to excel or be nationally competitive in the near future are given below. The initiative requires two new faculty positions and additional resources, which are also discussed below.

- **Low-Power Processors:** Development of microarchitectural features and programming techniques that minimize power consumption of processors in wireless devices.
- **RF Integrated Circuits:** Development of low-power RF integrated circuits for wireless applications.
- **Microfabrication:** Fabrication of MEMS for wireless and broadband applications. This includes developing MEMS technology for integrating components made by MEMS such as high Q inductors and tunable capacitors with CMOS circuits on the same chip for RF wireless and Bluetooth applications. This also includes the development of MEMS optical switches, filters, micro-lens arrays and gratings for broadband optical network applications.

- **Photonics:** Fiber materials, high-speed lasers and detectors, tunable lasers, wavelength converters, photonic switches and add/drop multiplexers.

A basic device fabrication capability already exists in the Electronic Material and Device Laboratory in the department. High-aspect ratio microstructures and LIGA capability are available at CAMD. However, LSU does not have any circuit fabrication capability. This deficiency is addressed through a separate institutional infrastructure enhancement proposal [1]. Equipment for RF circuit design and electrical measurements is included here in Appendix B. Equipment for the optical communication laboratory is requested under Appendix A.

5. Applications

Leveraging the facilities and expertise on mobile and ad-hoc networking, the initiative will pursue investigations in next-generation wireless applications. Some of these improve existing devices, for example, video-capable multimedia cell phones and affordable broadband wireless Internet access. Distance learning will be enhanced by two-way video communication for eye contact between an instructor and a student asking questions; this will be enabled by work in quality-of-service and multimedia techniques.

Other, exotic, applications will weave cell-phone and wireless PDA devices with tiny wireless sensors and an information infrastructure to provide, for example, location and status of perishable stock moving around a warehouse. Ad-hoc networks, in which a cell phone participates, will allow the exchange situation-specific information with nearby devices, for example, having the cell phone tell a nearby ticket vending machine to print a ticket for the usual trip home.

Whole new industries may develop around some of these applications; the initiative will help ensure that Louisiana is a center for some of that activity.

The initiative will require one new faculty member in this area with expertise in multimedia, wireless system architecture and distributed applications.

6. Summary

The state of Louisiana faces great challenges in developing and harnessing different aspects of information technology. Broadband and wireless technologies play a key role in this context. The proposed initiative in wireless and broadband technologies will provide an opportunity for LSU to conduct nationally competitive research in this area, develop and support local industry in these technologies, and educate students trained in state-of-the-art communication technology. Coupling current LSU resources and expertise with new faculty and research infrastructure will induce a productive synergy that can lead LSU to a nationally prominent role in wireless and broadband advances.

1. Institutional infrastructure improvement for LSU entitled "Microfabrication, Materials and Device Technologies for IT," submitted to LSU CAPITAL by CAMD and the Department of Electrical and Computer Engineering.

Appendix A

Wireless and Broadband Laboratory

The mission of the Wireless and Broadband Laboratory is to become a world-class research facility that will serve to advance fundamental research, train highly qualified telecommunication engineers and transfer technology to industry. We envision an experimental facility with gigabit connectivity among servers, high-speed wireless interconnection and routing among nodes, with ancillary equipment to support research in communications and signal processing and to implement demanding user oriented applications such as multimedia and eventually virtual reality. In the following, the equipment prices show the estimated cost.

1. Wireless and Networking

Computers with wireless networks adapters with sound and video cards (40 sets)	$ 160k
Workstation (5)	50k
Router, switch, bridges, adapters – T3, token ring, FDDI, ATM (3 sets)	90k
Accessories (logic analyzer, RF signal generator, pattern generator, etc)	150k
Protocol, network and spectrum analyzers	200k
Software (OS for wireless net, IOS)	15k
Software licences (OPNET, communication system tools etc.)	75k
Oscilloscopes (analog, digital, sampling, etc.)	20k
Optical switching platform, including spectrum analyzer	100k
Multi-channel equipment (data acquisition, fading simulator, radio platform)	80k
Broadband network equipment such as DSL cable modem, CMTS and DSLAM	120k
Miscellaneous (network node manager, storage device etc.)	30k
	$1.09M

2. Optical Network

Physical hardware (vibration isolated tables, beam control and micropositioning systems), high-frequency sampling oscilloscope, high-frequency signal generator/laser driver	$ 65k
High-speed photonic components (laser/detector arrays, tunable lasers)	100k
Optical components (lenses, filters, gratings, birefringent systems)	30k
Grinding and polishing equipment	50k
Software associated with ray tracers and layout tools	5k
	$250k

3. Signal Processing

Digital signal processors and development boards (TI TMS-series) and mis – cellaneous code libraries.	$ 30k
Development tools (code composer, RIDE graphic environment)	55k
Audio, video, imaging equipment	20k
	$105k

Appendix B

Electronic Design and Simulation Laboratory

1. RF IC and System Design

The RF (radio frequency) front-end in wireless systems is full of challenges, which are associated with multimode and multiband systems relating antennas, switches, filters, low-noise amplifiers, power amplifiers, synthesizers, adaptive networks and MEMS (micro-electro-mechanical systems). We propose to develop a first class research infrastructure with this laboratory for design, implementation and testing of RF front-end integrated circuits and systems for advanced wireless systems and for training students in the vital area of wireless communication.

A request for xenon diflouride etching system is made as an integral part of RF IC and system design laboratory to help integrate MEMS structures with electronics. The RF wafer probe station, which will be linked with other equipment, will allow us to test RF integrated circuits and MEMS devices at the wafer level. A combination of RF signal generator, vector analyzer, power supplies, power meter and power sensor with power amplifier design director system will allow us to design power amplifier modules at the very front-end of an RF system. The proposed infrastructure will allow us to design next generation of wireless systems.

List of Equipment

Vector signal and spectrum analyzers	$105 k
Cascade RF wafer probe station	65 k
Cadence and Eagleware EDA Toolsfor 3 years @$20,000/Year	60 k
Xenon diflouride etching system	50 k
Parts, accessories, scopes, RF signal generators, power supplies, power meters, transition analyzer etc.	170 k
MEMs CAD system	15 k
Power amplifier design system	40 k
	$505k

2. Simulation and Prototyping

The requested infrastructure will provide the software and equipment needed to design and simulate digital, analog, and mixed-signal circuits and to prototype digital circuits for communication and computer applications. In addition, the requested equipment and software will serve as a valuable resource for incoming and existing faculty in all areas of wireless and broadband technology.

The request includes a 12-way multiprocessor server and workstations for performing simulations, analyses, and running electronic design software. These would be housed in our existing machine room and workstation laboratories. The 12-way (64-bit) multiprocessor will be used for running advanced simulation and analysis programs, which cannot run efficiently on clusters of 32-bit machines. A request for a Terabyte of storage for the server is included as well. In addition, we request for thirty five engineering workstations and thirty five PCs to upgrade our existing IT faculty and student workstations and PCs, provide access to these for new faculty who will be hired as part of this initiative; ten of these workstations and ten of the PCs requested will be used for the RF IC and System Design thrust. Large simulations and analyses will be run on the campus computing cluster proposed as part of the LSU campus IT initiative. We request hardware needed to prototype digital devices using field-programmable gate arrays (FPGAs), and annual support fee for design tools from vendor of electronic design automation (EDA) with a higher-education program (HEP). The request also includes funds for purchasing IP (intellectual property) cores, which are pre-designed hardware components, for use in designing communication hardware. Software for simulation of communication systems, such as OPNET is also requested. Also, funds are requested for miscellaneous small software packages.

List of Equipment

Thirty five engineering workstations and thirty five PCs	$195 k
Two switches and connectors, etc for connecting workstations and PCs	4 k
One Terabyte worth storage for the server	15 k
Twelve-Way Multiprocessor Server	200 k
Two FPGA Development Systems	2 k
FPGA devices and supplies	1 k
EDA Software HEP annual support fee for three years	20 k
Assorted intellectual property (IP) cores	10 k
Simulation software, such as OPNET	10 k
3,000; Software and supplies for three years	3 k
	$460 k