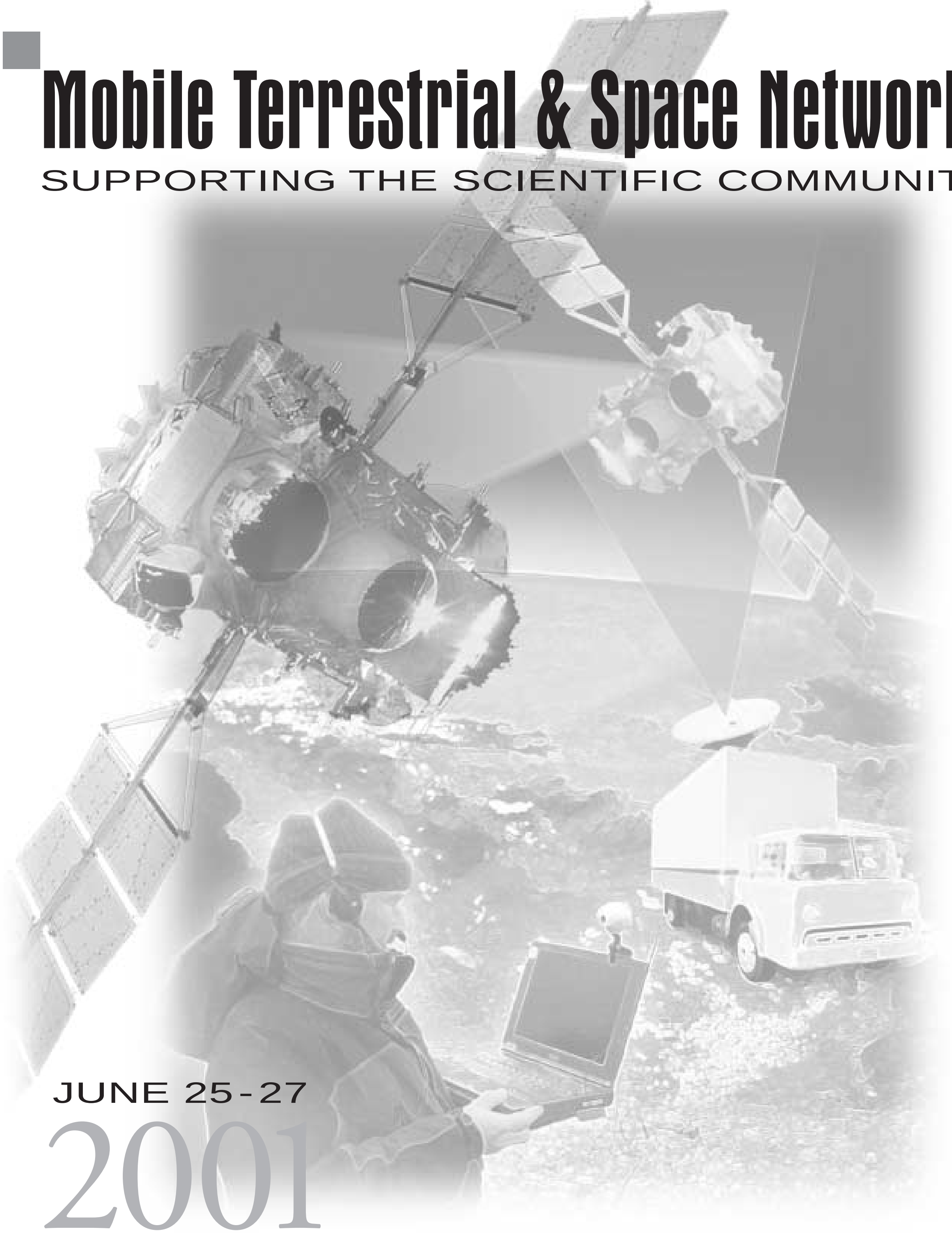
Mobile Terrestrial & Space Networking

SUPPORTING THE SCIENTIFIC COMMUNITY

WORKSHOP



JUNE 25-27

2001

NASA AMES RESEARCH CENTER

Welcome

Welcome to the 6th annual NREN workshop, "Mobile Terrestrial and Space Networking: Supporting the Scientific Community."

Over the years NREN workshops have focused on various aspects of emerging networking technologies of interest to the Next Generation Internet community. For example, in 1998 the NREN workshop explored Quality of Service issues, in 1999 the workshop produced recommendations to help bridge the gap from networking technologies to applications, and in 2000 the workshop targeted gigabit networking. This year the topic is mobile networking.

Mobile networking will enable exciting new paradigms for NASA science and engineering, enhancing support for missions that extend into remote areas where it is not economically feasible to create a permanent wired communications infrastructure. Three technological components of mobile networking to support the scientific community include satellite communications, wireless networking, and sensor networks. Our vision is seamless integration of these technologies to provide anytime, anywhere networking throughout the universe.

Specific objectives of this workshop include:

- Characterize the various mobile/wireless/satellite technologies that are capable of supporting applications involving high-resolution multimedia
- Examine how heterogeneous networks can be integrated to form a seamless end-to-end path
- Identify how scientific applications will be enabled and enhanced by mobile terrestrial and space networking

During the first afternoon of the workshop, demonstrations and presentations of applications will motivate the need for mobile networking. The second day will feature presentations on the individual technologies—satellite communications, wireless, and sensor networks. The third day will begin with a panel addressing seamless integration issues. Then we will divide into breakout groups to identify major barriers to achieving seamless integration, and to discuss what can be done (and on what timeline) to reach this goal. A report summarizing workshop activities will be published after the workshop.

On behalf of the NREN Project, thanks to the many people who have made this workshop possible: the National Science Foundation and Qwest, who are co-sponsoring this workshop; the workshop planning team, including virtually the entire NREN staff; the speakers who are sharing their ideas with us in their presentations; the demonstrators of their satellite and wireless applications; and all of you who are attending. We are also indebted to the High Performance Computing and Communications (HPCC) Program and to the NASA Advanced Supercomputing Division, which currently provide an organizational home to the NREN Project.

Thanks for coming. We appreciate your participation, and we anticipate a stimulating next three days.

Marjory Johnson
NREN Associate Project Manager

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Workshop Arrangements

Please direct all general questions to NREN staff.

- Marjory Johnson, Workshop Chair
- Dick desJardins and Taieb Znati, Co-chairs of the Program Committee
- Sally Miller, Pat Kaspar and Mike DeFrenza, Co-chairs of the Local Arrangements Committee

LOCATION:

The Moffett Training & Conference Center - Building 3, NASA Ames Research Center, Moffett Field, California.

MESSAGES:

The Registration Desk will accept messages for workshop participants at 1-650-604-2206. Messages will be delivered to the recipient. There are phones throughout the facility for your use. Dial 7 to get an outside line.

COMMUNICATIONS AND MESSAGE CENTER:

Two PCs with network connectivity will be available for participants to access the Internet and their email. Six Ethernet ports will be activated for participants to plug in their laptops.

NREN will also be deploying a Lucent WaveLAN wireless LAN at the workshop. If you bring a laptop with a compatible card you will be able to get email, surf the Web and download software from inside the conference rooms. We will be providing dynamic IP addressing, and if you think you may encounter firewall problems, check with your local administrator.

Compatible cards include:

Lucent WaveLAN PC Card 802.11b Turbo 11 MB Bronze or Silver

Lucent WaveLAN PC Card 802.11b 2 MB

Other 11 MB 802.11b DSSS

Some 802.11b DSSS 2 MB

802.11 frequency hopping spread spectrum cards will not work with the Lucent equipment.

If you are buying a new card for use at the meeting, we suggest you buy Lucent WaveLAN PC Card 802.11b Turbo 11 MB Bronze or Silver. We will be able to help users with configurations and troubleshoot any problems if they have one of these cards.

If you have any questions about the wireless LAN, or if your card will not work with the system, contact NREN staff.

RESTROOMS:

Restrooms are available on the north side of the Ballroom as well as off the front lobby (Main Entrance).

2001 WORKSHOP

AGENDA 1

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Agenda

MONDAY, JUNE 25

12:00 – 13:30 REGISTRATION/LUNCH

13:30 – 13:40 WELCOME AND LOGISTICS

13:40 – 15:40 APPLICATIONS

Enabling Mobility for NASA
Michael Cauley, NASA Glenn Research Center

High-Bandwidth Point-to-Point Western Multiplex Wireless
Donald Arndt, Western Multiplex

Web-Based, Distributed Simulation of an Aeronautical Propulsion System
Robert I. Griffin, NASA Glenn Research Center

Free Space Laser Communication
Phillip Dykstra, WareOnEarth Communications, Inc.

TCP Westwood: Enhanced TCP for Error-Prone Large Pipes
Mario Gerla, Giovanni Pau, and M. Y. Sanadidi, University of California at Los Angeles

TDRSS Access to the Internet
Dave Israel, NASA Goddard Space Flight Center

15:40 – 16:00 BREAK

16:00 – 17:30 APPLICATIONS CONTINUED

Communication Requirements for Remote Science Facilities
Mark León, NASA Ames Research Center

Satellite Communications to the South Pole
Thom Stone, NASA Ames Research Center

High Performance Wireless Research and Education Network
Hans Werner Braun, San Diego Supercomputer Center

HDTV Via Satellite
Dave Beering, Infinite Global Infrastructures, LLC

International Cooperative Experiments in Satellite Communications
Naoko Yoshimura, Communications Research Laboratory

Wireless Visible Human
Brian Athey, University of Michigan; Thomas Hacker, University of Michigan;
and Stuart M. Pomerantz, Carnegie Mellon University

17:30 – 19:30 SOCIAL RECEPTION

During this time demo presenters will be available for one-on-one discussions about their demos.

Agenda

TUESDAY, JUNE 26

07:30 – 08:30 CONTINENTAL BREAKFAST

08:30 - 09:00 WELCOME AND LOGISTICS

Director's Office, NASA Ames

Kenneth Freeman, NASA NREN

Taieb Znati, National Science Foundation

09:00 – 10:00 KEYNOTE

Charles E. Perkins, Nokia: **Billions: Can We Do It?**

10:00 – 10:30 BREAK

10:30 – 12:00 NEXT GENERATION SATELLITE SYSTEMS AND SERVICES

A Brief History of Satellite / Terrestrial Network Interoperability Studies
David Beering, Infinite Global Infrastructures, LLC

Architectures and Protocols for Next Generation Satellite Networks
Eytan Modiano, Massachusetts Institute of Technology

Space Networking: Enabling NASA's 2010 Visions for Science and Exploration
Kul Bhasin, NASA Glenn Research Center

R&D Plans for Japanese Next Generation Satellite Communications Systems
Naoto Kadowaki, Communications Research Laboratory

12:00 – 13:30 LUNCH

13:30 – 15:00 NEXT GENERATION WIRELESS

Wireless Networking: Current Status and Issues Facing the Next Generation
Magda El Zarki, University of California, Irvine

Ad Hoc Networks—A New Communication Paradigm?
Zygmunt Haas, Cornell University

Implementation and Testbed Experiences in the Caterpillar Mobile Communications System Project
David B. Johnson, Rice University

15:00 – 15:30 BREAK

Agenda

TUESDAY, JUNE 26 CONTINUED

15:30 – 17:00 SENSORS AND SENSOR NETWORKS

Research Challenges in Embedded Networked Sensing
Deborah Estrin, University of California, Los Angeles/University of Southern California, Information Sciences Institute

A Distributed Robotic Sensor Network for Tracking and Coverage
Gaurav Sukhatme, University of Southern California

A Remote Ecological Micro-Sensor Network (a.k.a. Pods)
Brian Chee, University of Hawaii

WEDNESDAY, JUNE 27

07:30 – 08:30 CONTINENTAL BREAKFAST

08:30 – 10:00 SEAMLESS INTEGRATION PANEL

Overview: Panel Chair, David B. Johnson, Rice University
Individual Panelist Perspectives

John Baras, University of Maryland, College Park
J.J. Garcia Luna, University of California, Santa Cruz
Dave Israel, NASA Goddard Space Flight Center
David B. Johnson, Rice University
Wesley Kaplow, Qwest Communications
Willie Lu, Infineon/Siemens

10:00 – 10:15 BREAK

10:15 – 10:30 BREAKOUT GROUP INSTRUCTIONS

10:30 – 12:00 BREAKOUT GROUPS

12:00 – 13:00 WORKING LUNCH

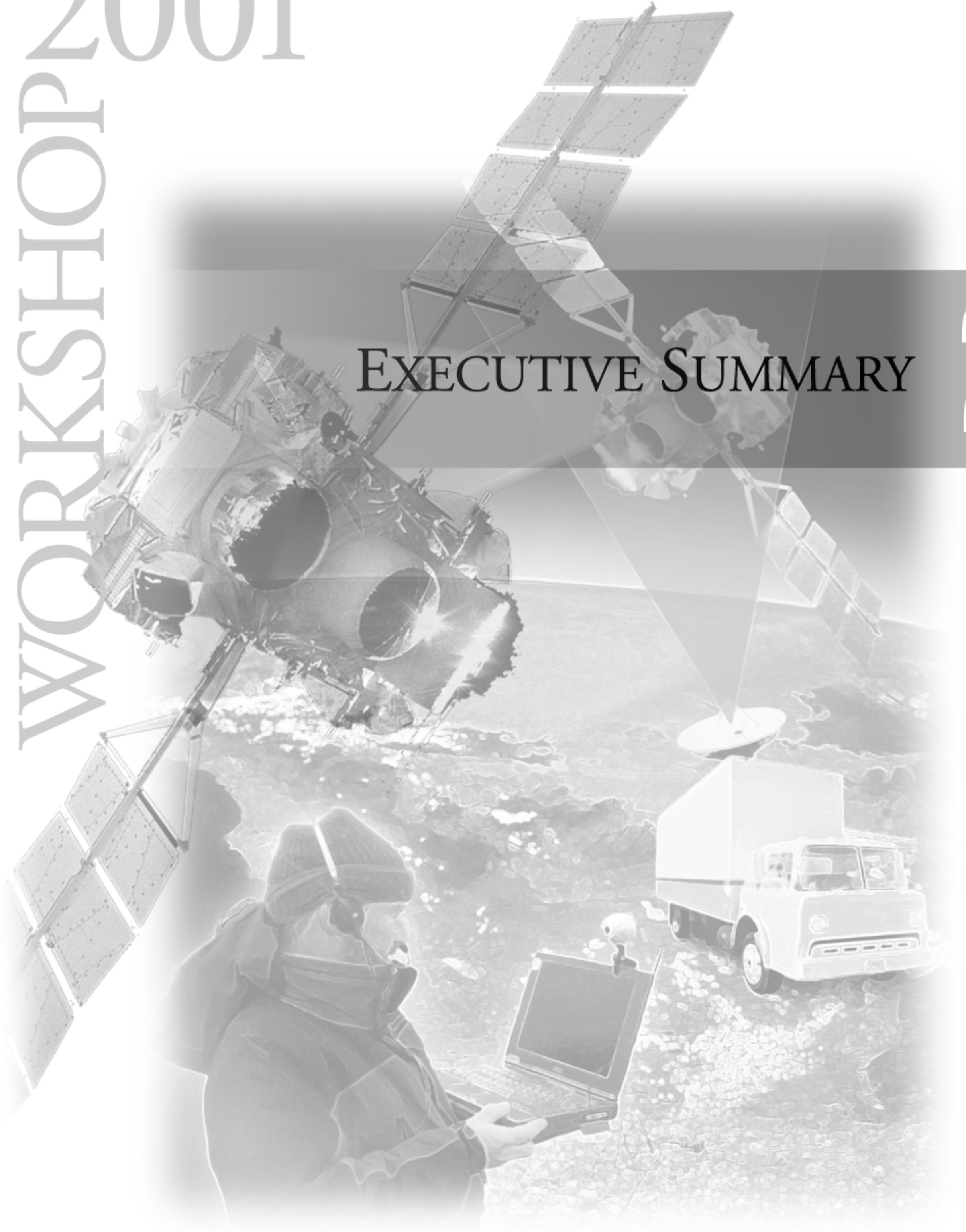
13:00 – 15:30 BREAKOUT GROUPS CONTINUED

15:30 – 16:00 BREAK

16:00 – 17:00 BREAKOUT GROUPS REPORTING AND WORKSHOP WRAP-UP

WORKSHOP 2001

EXECUTIVE SUMMARY 2



Executive Summary

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Introduction

The 2001 NREN workshop, "Mobile Terrestrial and Space Networking: Supporting the Scientific Community," was held at NASA Ames Research Center on June 25-27, 2001. Mobile networking was selected as the theme for the workshop because of its enormous potential for enhancing NASA missions, many of which require access to people or equipment in remote locations. NREN's vision is to provide communications support for mobile and nomadic science, whether on Earth or in space. That is, the same computer/communications services should be available to a scientist or engineer while working off site or in the field as at his home site, and these services should be available using the same familiar user interfaces. Wireless and satellite mobile networking technologies, together with the seamless integration of wired and wireless technologies, are key to providing the necessary capabilities to realize this vision.

The mobile satellite dish parked just outside the conference center figured prominently in workshop activities. Developed by NREN/NASA Glenn Research Center (GRC) to provide temporary network connectivity in relatively inaccessible areas or for prototyping new technologies, this new facility is officially called the NREN/GRC Transportable Earth Station (TES). It consists of a trailer equipped with a twelve foot satellite antenna and supporting electronics, along with a van to pull the trailer. This endeavor represents a first step toward providing support for mobile and nomadic science within NASA. The TES can be driven to a site, parked, the antenna deployed, and the system used for satellite access to provide temporary networking facilities at that site. Potential applications of the TES include support for mobile networking technology development, workshops and conferences, scientific field studies, and international collaborations.

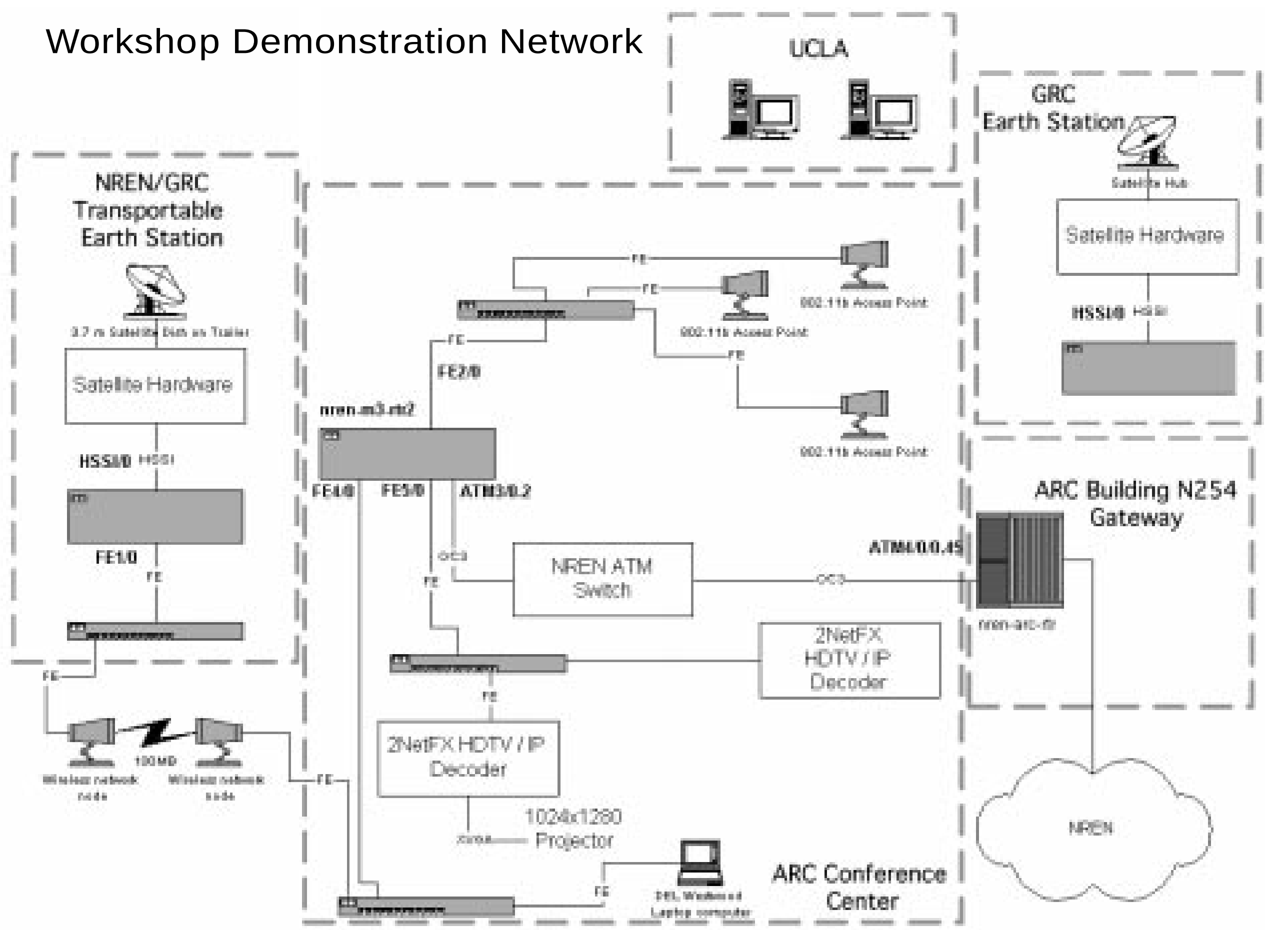
This executive summary presents highlights of the various workshop activities. More detailed information, including PowerPoint slides for each of the workshop presentations, is available on the NREN web site at http://www.nren.nasa.gov. The Breakout Group Discussions and the Workshop Conclusions sections of this summary highlight some of the most difficult challenges to achieving seamless integration between the various wireless and wired technologies. Ideas contained in these sections could provide an initial outline for developing guidelines for future Federal agency research programs.

NREN gratefully acknowledges the valuable contributions of the National Science Foundation, which cosponsored the workshop and which shares the NREN vision for mobile and nomadic science; corporate cosponsor Qwest; and the many vendors who generously provided their time and equipment to support the workshop demonstrations.

Workshop Activities

APPLICATION DEMONSTRATIONS AND PRESENTATIONS

The first afternoon of the workshop was devoted to demonstrations and presentations of applications of satellite and wireless technologies, emphasizing the utility of the technologies to reach hard-to-access locations. Engineers combined wireless, satellite, and fixed terrestrial components to configure the network to support the workshop demonstrations. The focal point of this network was the NREN/GRC Transportable Earth Station, which was used to connect to several commercial satellites. In addition a Western Multiplex wireless antenna was mounted on top of the TES equipment box, with a matching antenna mounted on the roof of the conference center. The combination of the TES and the pair of Western Multiplex antennas provided tetherless connectivity from off-site satellite ground stations via the TES into the conference center.



Workshop Activities

The aviation safety application, the HDTV over satellite demonstration, and the TCP-Westwood demonstration all utilized the TES. The aviation safety demonstration, utilizing completely tetherless connectivity from GRC into the conference center, illustrated how an off-site scientist could use a combination of wireless and satellite technologies to access simulation capabilities located at his home institution. The communications model for this demonstration represents how wireless and satellite capabilities can be combined to enable a scientist in the field to access computer facilities and colleagues at his home institution, thus supporting scientific field studies. The HDTV over satellite demonstration, using the TES to uplink a high-resolution (1024 X 1280), 18 Mbps video stream, served as a prototype for transmitting high-resolution video from the Space Station to scientists at their home institutions back on Earth.

The TCP-Westwood demonstration compared the performance of a standard implementation of TCP with the modified TCP-Westwood version, which was designed to enhance performance over long-delay, lossy links, such as satellite and wireless. Two copies of an image taken from a telescope located in a remote region of Arizona were transmitted simultaneously from UCLA to NASA GRC via terrestrial networks. From the ground station at GRC the signal was transmitted via satellite to the TES and then via wireless into the conference center, where the images were projected onto the screen as they were being downloaded. The difference in the rate of transfer of the two images was easily visible. Achieving efficient file transfer to distribute data observations from this remote telescope site to university researchers is a real problem that is currently being investigated. An acceptable solution is likely to involve satellite and wireless technologies, since high-speed terrestrial networking links are not available anywhere close to the telescope location.

Another group of presentations demonstrated the use of the NASA Tracking and Data Relay Satellite System (TDRSS), the satellite system used to support NASA operational space missions. In one presentation/demonstration TDRSS was used to access the South Pole Station to enable a live videoconference between the NREN Project Manager at NASA Ames Research Center and several people stationed at the bottom of the Earth. This videoconference could only be conducted during the evening, since the inclination of the satellite orbit limits TDRSS access to the South Pole to only a few hours each day; a videotape was shown at the workshop. Scientists at the South Pole enthusiastically described how their science could be enhanced by improved communications with colleagues around the world.

Another TDRSS demonstration included the use of a portable TDRSS antenna that was brought to the workshop site. This portable TDRSS antenna, housed in a 3x3x3 cubic foot container, was used to connect to the Internet at the workshop. In the past this portable antenna has been used to provide temporary communications capabilities to support projects in remote areas throughout the world, including an expedition to the North Pole in 1999.

The final demonstration at the workshop illustrated how wireless could be used to enable a group of co-located professionals to access database

Workshop Activities

images on individual laptops while working together in a classroom or auditorium setting. Workshop participants were able to access the National Library of Medicine Visible Human dataset individually, while the presenters described the dataset and demonstrated its use to the group as a whole. Images from the dataset were transmitted from an image server at the Pittsburgh Supercomputer Center to the conference center and then distributed via wireless to the workshop participants, who viewed the images on their individual laptop computers.

The remainder of the first afternoon of the workshop was devoted to technology presentations and descriptions of projects utilizing satellite and wireless technologies.

TECHNICAL PRESENTATIONS

Technical presentations on the second day of the workshop addressed three components of mobile terrestrial and space networking: satellite communications, wireless networks, and sensor networks.

The keynote address opened with the prediction that there will be one billion mobile devices on the Earth next year and that wireless/mobile nodes will eventually dominate the Internet. Such predictions clearly underscore the importance of mobile networking and seamless integration of heterogeneous networking technologies.

The satellite communications session included an examination of current satellite capabilities and several different perspectives on future directions, including:

- New satellite architectures using processing within the satellite to enhance system performance
- A NASA vision for integrating space and terrestrial networking to provide communications support for formation flying, inter-spacecraft networks, user control of experiments on the Space Station, and interplanetary networking
- Japanese plans for deploying a next-generation gigabit satellite system in 2005

The presentations during the wireless session included an overview of wireless technology (including the current status of standards and a discussion of obstacles to seamless integration), a presentation of the challenges of ad hoc networking, and a presentation of experiences implementing a global mobile wireless network.

Workshop Activities

The session on wireless sensor networks opened with a presentation of a vision for embedded sensor systems, including research challenges and opportunities. This was followed by presentations of two specific sensor network applications, preservation of rare plants in Hawaii and distributed robotics.

Although these presentations primarily addressed the individual technologies, many comments addressed the problem of seamlessly integrating wired and wireless systems:

- IP is the glue that will hold together heterogeneous networks.
- Only IPv6 offers sufficient address space and other features necessary to support mobility.
- Security is a major issue for wireless technologies.
- Business and regulatory issues have as much (maybe more) impact than technology.
- Applications must be able to adapt to the underlying communications infrastructure.
- Protocol issues at the network, transport, and application layers (in addition to the data link layer) must be addressed to achieve mobility and nomadicity.
- Modifications of file systems, database access, and web access are also important for nomadicity.
- Unexpected issues can arise during implementation of a system.

PANEL ON SEAMLESS INTEGRATION

The panel members were selected because of their expertise with either wireless or satellite systems and because of their experience in deploying and integrating heterogeneous wired and wireless systems. The purpose of the panel was to set the stage for the subsequent breakout discussions.

It was noted during the panel discussion that progress is being made toward the realization of seamless integration:

- Seamless integration has been achieved within research projects.
- Commercially available wireless routers enable peer-to-peer wireless.
- There is ongoing work to develop an interface between commercial routers and existing RF equipment for satellite/terrestrial integration.
- There are several active protocol-development efforts (e.g., Mobile IP, TCP modifications).

Some obstacles to seamless integration that were raised by panel members include:

- A killer application has not yet been identified.
- Routing across heterogeneous networks is a challenge.
- Providing service guarantees across heterogeneous networks is a challenge.
- TCP performance is poor over wireless links.
- Experience is limited.

Workshop Activities

BREAKOUT GROUP DISCUSSIONS

As the final workshop activity, participants formed two discussion groups. Each group was given the same assignment:

- Define seamless integration of mobile terrestrial and satellite networking.
- Identify major technical challenges to achieving seamless integration.
- Identify the next steps.

The two breakout groups approached the seamless-integration problem from different perspectives. The first group viewed the problem from the perspective of people with different roles — end user, system manager, and developer. The second group viewed the problem from different levels of the overall networking system — the end user, the application or appliance representing the end user to the network, the network interface, and finally the network itself. Nevertheless, the two groups generated similar ideas; consequently, ideas presented within the two groups are merged below.

Definition of Seamless Integration

Two themes that seemed to be central to the various perspectives on the meaning of seamless integration are:

Same as standard wired system — same level of security, same user interface, same data integrity, same services

Easy — easy to use, easy to manage, easy to diagnose, easy to deploy, easy to configure and reconfigure

Other key ideas included predictable performance, with the user being able to control performance tradeoffs and to negotiate services via the network interface; and smart, adaptable applications.

Challenges to Achieving Seamless Integration

The following framework combines the lists of challenges to achieving seamless integration that were identified by the two breakout groups:

- Physical resource issues:
  - Power limitations
  - Shortage of spectrum (efficient use and reuse of)
  - Multi-user interference
  - Terrain obstacles
- Protocol issues:
  - Protocols for wireless
  - Adaptive protocols (TCP, HTTP)
  - Adaptable backbone
  - Integration of routing for different types of networks
  - Routing for multi-hop ad hoc networks
  - Asymmetric routing and links
  - Interoperability of standards
  - Multipoint (broadcast, multicast, and reliable multicast)
  - Scalability - number of nodes, amount of mobility, communication pattern, types of heterogeneous systems, terrain and obstacles to line of sight

Workshop Activities

- Upper layer protocol issues
- Common air interface for user interface to satellites

• Application development:

- Applications for wireless (tolerate latency and variability)
- Killer application
- Adaptive applications

• Network services issues:

- Security
  - Identification of end user
  - Trust
  - Privacy
  - Integrity
  - Denial of service
  - Key generation and management
  - Trust models and authentication
- QoS
- Bandwidth on demand
- Translation of requirements between user and backbone
- Achieving context awareness
- Agreeing on definition of things that can be requested from the network

• Performance issues:

- Measurement, simulation, and validation
- Performance evaluation
- Cross-layer control, adaptation, and integration across application and protocol layers
- Providing quick access to the backbone, reducing the number of hops (wireless provides considerably less bandwidth)

• Non-technical issues:

- Regulatory
- Economic
- Business

Next Steps

Several ongoing activities were identified within the breakout discussions, and some solutions to specific challenges were proposed. Perhaps the most important information is the following list of issues that are currently NOT being addressed, and which therefore might be suitable candidates for inclusion in future Federal agency research programs.

- Major large-scale integrated wireless testbeds
- Validation of large, complex wireless simulation and analytical models
- Human interface standards
- Unified cross-layer control, adaptation, and integration across protocol and application layers
- Autonomous intelligent management of large integrated wireless systems
- Standards for energy-efficient protocols for ad hoc and sensor networks

Workshop Conclusions

Mobile networking is an important research area today, and will assume increasing importance as the number of mobile nodes explodes over the next few years. Several ongoing research activities are making significant progress in addressing the many challenges presented by mobile networking and nomadicity. For example, multiple IETF working groups are addressing key protocol issues, TCP is being modified to support satellite and wireless systems, and satellite services are rapidly becoming more widely available.

Some issues were recurring themes throughout the workshop. Participants repeatedly emphasized that IP is the glue for integrating heterogeneous networks. This reinforces the importance of ongoing IPv6 and MobileIP activities and experimentation using IP over satellite, e.g., the NASA Operating Missions as Nodes on the Internet (OMNI) Program. Yet, mobility must be addressed at all layers of the protocol stack.

Other issues emphasized during the workshop include the importance of adaptability (i.e., applications must be adaptable, the network backbone must be adaptable, and the user must have some control to select tradeoffs in services from the underlying infrastructure), the necessity of providing Service Level Agreements to the end user, the difficulties in providing services such as QoS and multicast in wireless and mobile environments, and the inherent difficulties in providing security.

The workshop was successful in bringing together a diverse group of experts from academia, industry, and government to explore both the challenge and the exciting potential of mobile networking. Ideas generated during the workshop will provide valuable input during planning of future networking activities within NASA and other individual Federal agencies, as well as planning of future government-sponsored research initiatives.

APPLICATIONS 3

Applications

3

Enabling Mobility for NASA
Michael Cauley, NASA Glenn Research Center

High-Bandwidth Point-to-Point Western Multiplex Wireless
Donald Arndt, Manager of Technical Marketing, Western Multiplex

Web-Based, Distributed Simulation of an Aeronautical Propulsion System
Robert I. Griffin, NASA Glenn Research Center

Free Space Laser Communications
Phillip Dykstra, WareOnEarth Communications, Inc.

TCP Westwood: Enhanced TCP for Error-Prone Large Pipes
Mario Gerla, Giovanni Pau, and M. Y. Sanadidi, University of California at Los Angeles

TDRSS Access to the Internet
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Communication Requirements for Remote Science Facilities
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Naoko Yoshimura, Communications Research Laboratory, Japan

Wireless Visible Human
Brian Athey, University of Michigan; Thomas Hacker, University of Michigan; and Stuart M. Pomerantz, Carnegie Mellon University

Enabling Mobility for NASA

Michael Cauley, NASA Glenn Research Center

On Monday June 4, 2001, the NASA Glenn Research Center accepted delivery of the new NREN/GRC Transportable Earth Station (TES). The Transportable Earth Station is designed to support high data rate networking experiments into highly remote areas where terrestrial connectivity is poor or non-existent. The earth station is a completely self-contained Ku-band system, able to simultaneously send and receive up to 50-Mbps data streams. The station is mounted on a 20'-long trailer and is towed by an Econoline van. No special permits or licenses are required to drive the van and trailer across public highways.

The first "maiden" deployment of the TES will be to support the upcoming NREN Workshop VI on "Mobile Terrestrial and Space Networking." The workshop will be held at NASA Ames. The new TES will be parked at NASA Ames and be connected via satellite to the TESLA earth station here at NASA Glenn. For the workshop, the NREN network will be connected to Glenn's large earth station located in the center West Area. For this demonstration, we will configure a two-way, full duplex 45-Mbps satellite communications channel between NASA Ames and NASA Glenn.

The TES antenna is a highly ruggedized 3.7-meter (12-foot) diameter Andrew "tri-fold" antenna. The two outer sides of the antenna are hinged and fold back inside the antenna for transport. The antenna is accurately pointed using variable speed drive motors. The trailer includes a large air-conditioned equipment shelter mounted on a special suspension system to protect the equipment from damage during transport. The equipment shelter includes rack mount rails for supporting the specialized equipment needed by various experiments. Also mounted to the trailer is a Kubota 12.5-kW diesel generator for electrical power. The generator is able to run at full load for 8 hours from its 10-gallon tank. The generator has considerable excess capacity available to power almost any experiment. The fuel tank can be filled while set up at a remote location using two ordinary 5-gallon gas cans.

The earth station has a blanket license to operate through any domestic Ku-band satellite from anywhere within the U.S. and its possessions. Authority to transmit to International satellites is done on a case-by-case basis with a simple endorsement modification to the license.

The TES is highly flexible and may be used to support networking demonstrations at conferences, or to support researchers from highly remote areas. Other applications might include distance education to Native American Indian Tribal Colleges, or to partner with other government / university / industry organizations interested in performing high-speed networking research. Other future applications may include high bandwidth transoceanic communication links into foreign countries.

High-Bandwidth Point-to-Point Western Multiplex Wireless

Donald Arndt, Manager of Technical Marketing, Western Multiplex

The Western Multiplex 100-Mbps wireless point-to-point link installed for the workshop provides tetherless connectivity between the NREN/GRC Mobile Uplink Trailer and the conference facility. This last-mile point-to-point link will be used for several of the workshop demonstrations. There is an antenna on the roof of the conference center and one on the trailer. These systems require line of sight and are effective at a distance of up to 30 miles.

In this presentation we will discuss the capabilities installed to support this workshop, and we will also discuss higher speed wireless offerings.

Web-Based, Distributed Simulation of an Aeronautical Propulsion System

Robert I Griffin, NASA Glenn Research Center

This application was developed to allow users on remote systems to simulate flight models and view engine data provided by NASA's Numerical Propulsion System Simulation (NPSS). A browser interface allows the user to specify the parameters of NPSS simulations by the selection of telemetric flight data and engine model requirements. Requested simulations are then split into sub-jobs and submitted to multiple remote machines that are located within NASA's Information Power Grid (IPG). The results of these executions of NPSS are returned to and maintained in a database by the Web server and may subsequently be reviewed in tabular form as well as in a series of X-Y Scatter plots. Technologies incorporated by this application include: Common Object Request Broker Architecture (CORBA), IPG/Globus, and Java Server Pages (JSP). This application is part of the Aviation Safety Project and represents a collaborative effort between NASA Glenn and NASA Ames Research Centers.

Free Space Laser Communications

Phillip Dykstra, Chief Scientist, WareOnEarth Communications, Inc.

The use of lasers for high-speed "last mile" solutions is becoming increasingly common. We look at the strengths and weaknesses of this technology compared to other solutions such as microwave. How to choose such a system is covered as is a brief look at the marketplace. A detailed example of experiences with an OC3 laser link in San Diego will be discussed.

TCP Westwood: Enhanced TCP for Error-Prone Large Pipes

Mario Gerla, Giovanni Pau, and M. Y. Sanadidi, UCLA Computer Science Department

TCP Westwood (TCPW) is a *sender-side-only* modification of the TCP congestion control algorithm that improves upon the performance of existing TCP implementations, especially over error-prone large pipes, e.g., satellite links, or mixed wired/wireless paths with long end-to-end propagation times. The key innovative idea in TCPW is to continuously estimate, at the TCP source, the bandwidth made available to the connection by monitoring the arriving ACKs and exploiting the information they convey. The bandwidth estimate is then used to compute the appropriate congestion window size and slow start threshold after a congestion episode.

The rationale of this strategy is simple: in contrast with TCP Reno, which "blindly" halves the congestion window after three duplicate ACKs, TCP Westwood selects a slow start threshold and a congestion window size which are consistent with the estimated available bandwidth at the time congestion is experienced. TCPW is particularly effective over wireless links where sporadic losses due to radio channel problems are often misinterpreted as a symptom of congestion by standard TCP schemes and thus lead to unnecessary window size reduction. Experimental studies reveal substantial improvements (in some cases, up to five-fold) in throughput performance. Fairness among TCPW connections sharing a bottleneck link has also been demonstrated; and friendliness to TCP Reno was observed in a set of experiments showing that TCP Reno connections are not starved by TCPW. Finally, TCPW has been shown to perform almost as well as localized link layer approaches (e.g., Snoop), without incurring the cost and overhead of a specialized link layer protocol or proxy. Unlike Snoop, TCPW is a sender-side-only modification and does not require inspection and/or interception of TCP packets at intermediate (proxy) nodes. Rather, it fully complies with the end-to-end TCP design principle.

During this workshop, we will demonstrate TCPW for representative NASA applications that communicate over terrestrial/satellite paths using the FTP/TCP protocol stack.

TDRSS Access to the Internet

Dave Israel, NASA Goddard Space Flight Center

NASA applications often require the use of portable equipment to provide connectivity for NASA scientists working in remote field areas. In this presentation we discuss a low-bandwidth (128 Kbps) solution that uses the "S" band transceiver on TDRSS (Tracking and Data Relay Satellite System). This is a portable solution providing IP services that has been utilized for applications at the North Pole. Our workshop demonstration shows access to the Internet via TDRSS.

Communication Requirements for Remote Science Facilities

Mark León, NASA Ames Research Center

NREN and the Learning Technologies Project (LTP) have partnered to develop solutions for communication requirements in the international arena. Specifically this talk will focus on two remote telescope facilities located in the mountains of Chile and the Outback area of Australia. Design options and current implementation designs will be covered.

Satellite Communications to the South Pole

Thom Stone, NASA Ames Research Center

Too remote and hostile for wired or microwave solutions and out of range of most geo-synchronous satellites, the North and South Poles have always presented a difficult challenge for networking. Just a few short years ago, the only links to the outside world were provided by short wave radio and an e-mail relay over a few polar-orbiting satellites. Now National Science Foundation (NSF) Polar programs use "inclined orbit" satellites to provide higher speed connections. Currently an old GOES satellite and TDRSS I are being used to provide links up to T1 speeds for several hours a day. This TDRSS link developed by Dave Israel of GSFC provides the highest speed link that is used to assist the science project at the Amundsen-Scott Station. Soon the NSF will be using MARISAT I, which was proven at the Pole by NASA some years ago, to provide an additional high-speed connection for several hours a day.

The time of satellite availability at the Pole changes each day and connectivity for our IP-based videoconference was not available during the hours of the workshop. Therefore, we recorded an interview by Ken Freeman during the evening and will play it for you at the workshop.

High Performance Wireless Research and Education Network

Hans Werner Braun, San Diego Supercomputer Center

The High Performance Wireless Research and Education Network (HPWREN) team is creating, demonstrating, and evaluating a non-commercial, prototype, high-performance, wide-area, wireless network in San Diego county. The NSF-funded network includes backbone nodes on the UC San Diego campus and a number of "hard to reach" areas in San Diego county. The HPWREN will not only be used for network analysis research, but will also provide high-speed Internet access to field researchers from several disciplines (geophysics, astronomy, ecology) and educational opportunities, such as rural Indian reservations and schools.

The UC San Diego interdisciplinary project is led by Hans-Werner Braun, a research scientist at the San Diego Supercomputer Center, and Frank Vernon, a geophysicist at the Scripps Institution of Oceanography.

HDTV Via Satellite

Dave Beering, Infinite Global Infrastructures, LLC

As a part of the Consolidated Space Operations Contract, Lockheed Martin Space Operations has developed an advanced end-to-end communications system architecture for NASA's Human-Rated spacecraft operating in Low-Earth Orbit. This architecture, which has been under development for three years, supports a host of advanced interactive multimedia applications, including the transport of High-Definition Television (HDTV). A full-scale working model of the end-to-end system was demonstrated at the National Association of Broadcasters annual convention in April of 2001 in Las Vegas, Nevada. That demonstration featured two HDTV feeds, a Standard Definition Television (SDTV) feed, and numerous interactive applications based on IP. The demonstration network included links on NASA's Tracking & Data Relay Satellite System and Loral Skynet's Telstar 6, in addition to a national-scale broadband network.

This demonstration will reprise a small portion of the NAB demonstration, namely the broadcast HDTV link utilizing Telstar 6. A 20-megabit per second HDTV feed will be originated at the Naval Research Laboratory in Washington, DC, where it will be uplinked to Telstar 6 using the Naval Research Laboratory's commercial Ku-Band satellite hub. The signal will traverse the Telstar 6 space segment and will be received at NASA Ames using the NREN portable satellite terminal. During the course of the broadcast, the HDTV signal will traverse several different transports, including Asynchronous Transfer Mode (ATM), Digital Video Broadcast, and IP. This demonstration illustrates the power of commercial standards for enabling the real-time delivery of first-generation digital video from the International Space Station to nearly anyone within the broadcast satellite's footprint.

International Cooperative Experiments in Satellite Communications

Naoko Yoshimura, Communications Research Laboratory, Japan

This presentation describes an international cooperative satellite communications and applications experiment carried out by CRL and foreign partners, and discusses the possibility of a future joint satellite communications and applications program between CRL and NASA.

Wireless Visible Human

Brian D. Athey, University of Michigan Cell & Developmental Biology
Thomas J. Hacker, University of Michigan Center for Parallel Computing
Stuart M. Pomerantz, Carnegie Mellon University, Pittsburgh Supercomputing Center

The Visible Human dataset has proven valuable to researchers needing high-quality anatomical images, but has still been of limited usefulness to health sciences anatomy students. In a classroom setting, it is desirable for groups of students to have individual access to the dataset and its derivatives such as renderings and database links. Furthermore, "free style" navigation of these fused knowledge sources is needed. Using image-viewing software developed by a collaboration of the University of Michigan and the Pittsburgh Supercomputing Center (PSC), users in a group setting can establish multiple parallel connections via a wireless LAN to a remote Visible Human image server and independently navigate the dataset, renderings, database, and www links in a free-style fashion. In addition, performance tuning of the network connection using the PSC/NCAR/NCSA Web-100 software will be demonstrated. This work is funded by the National Library of Medicine (NLM) Next Generation Internet (NGI) program.

WORKSHOP 2001

TECHNICAL PRESENTATIONS 4

Technical Presentations

4

Keynote Address

Charles E. Perkins, Nokia: **Billions: Can We Do It?**

Next Generation Satellite Systems and Services

A Brief History of Satellite / Terrestrial Network Interoperability Studies
David Beering, Infinite Global Infrastructures, LLC

Architectures and Protocols for Next Generation Satellite Networks
Eytan Modiano, Massachusetts Institute of Technology

Space Networking: Enabling NASA's 2010 Visions for Science and Exploration
Kul Bhasin, NASA Glenn Research Center

R&D Plans for Japanese Next Generation Satellite Communications Systems
Naoto Kadowaki, Communications Research Laboratory, Japan

Next Generation Wireless

Wireless Networking: Current Status and Issues Facing the Next Generation
Magda El Zarki, University of California, Irvine

Ad Hoc Networks—A New Communication Paradigm?
Zygmunt Haas, Cornell University

Implementation and Testbed Experiences in the Caterpillar Mobile Communications System Project
David B. Johnson, Rice University

Sensors and Sensor Networks

Research Challenges in Embedded Networked Sensing
Deborah Estrin, University of California, Los Angeles/University of Southern California, Information Sciences Institute

A Distributed Robotic Sensor Network for Tracking and Coverage
Gaurav Sukhatme, University of Southern California

A Remote Ecological Micro-Sensor Network (a.k.a. Pods)
Brian Chee, University of Hawaii

Technical Presentations

Keynote Address

Keynote Address

Billions: Can We Do It?

Charles E. Perkins, Nokia

Tremendous advances over the last 10 years have changed the nature and expectations of the global communications networks. Powerful wireless computers and voice terminals have nourished a future of “anytime, anywhere” Internet connectivity. While everyone seems to agree that this will happen, there is surprisingly little agreement on even the broadest details about how the underlying network will be architected to meet the challenge. In this talk, I will outline some of the problem areas, characterizing the challenges of mobility and some of the known solutions. Mobile IPv6 stands tall among the areas of chief current interest, and I will emphasize its potential role in helping to create the shape of the future networks. One of the chief challenges for the global Internet is simply to enable it to grow to the size needed to support all the wireless network nodes of the future. IPv6 is the most likely contender to provide the needed network-layer interconnection, since IPv4 solutions are hampered by lack of available address space. Given that, Mobile IPv6 fits very naturally, but is (on its own) not fully capable to solve all the problems associated with smooth handovers and roaming authorizations that are needed for the converged voice and data network of the future. Convergence and scalability, interoperability and economics, are all challenging forces driving the current efforts to find the appropriate network-layer solutions for mobile networking. The stakes are huge enough to justify the effort.

Technical Presentations

Next Generation Satellite Systems and Services

Next Generation Satellite Systems and Services

A Brief History of Satellite / Terrestrial Network Interoperability Studies

David R. Beering, Principal, Infinite Global Infrastructures, LLC

This presentation will describe a seven-year progression of experiments with the common objective of making satellite networks more interoperable with terrestrial networks and user applications, enabling NASA and its partners to perform better science. Early work utilized NASA's Advanced Communications Satellite (ACTS) and was substantially influenced by the oil industry. This work focused intensively on performance at the Transmission Control Protocol (TCP) layer and the boundary between satellite and terrestrial networks. More recently, the scope of activity has broadened to include TCP performance in the presence of link errors and congestion, as well as variable data rate / variable power satellite networks. Specific configurations have been built to study advanced network and applications concepts for the International Space Station and other NASA Low-Earth programs. Recent experiments have utilized a variety of satellites including GE-4, Galaxy 4r, Telstar 6, Telstar 11, and NASA's Tracking & Data Relay Satellite System (TDRSS). Future concepts developed through this work will also be discussed.

Next Generation Satellite Systems and Services

Architectures and Protocols for Next Generation Satellite Networks

Eytan Modiano, Massachusetts Institute of Technology

This talk summarizes several significant technical advances for next generation satellite networking. We describe new architectures and protocols for high-rate satellite networks designed specifically to support bursty data traffic, e.g., optimal energy allocation for communication satellites. We also describe routing and scheduling in multi-beam satellite systems as well as adaptive power and rate control techniques that achieve greatly improved data throughputs over time-varying satellite channels.

Next Generation Satellite Systems and Services

Space Networking: Enabling NASA's 2010 Visions for Science and Exploration

Kul Bhasin, NASA Glenn Research Center

The development of terrestrial Internet has led to the question particularly at NASA; can satellites and other space platforms become an Internet-node in space? This will allow the direct transfer of information directly from space to the users on Earth and even be able to control the spacecraft and its instruments. NASA even wants to extend the near Earth space Internet to deep space applications where scientists and the public here on Earth may view space exploration in real time via the Internet. NASA's future exploration will involve intensive in situ investigations of planets, moons, asteroids, and comets. While past missions typically involved a single fly-by or orbiting science spacecraft, future missions will begin to use fleets of small, highly intelligent robotic vehicles to carry out collaborative investigations. The resulting multi-spacecraft topologies will effectively create a wide area network spanning the Earth and the solar system. These ideas have led to the development of space communication network architectures that mirror the terrestrial Internet in its capability and flexibility. The notional requirements for future data gathering and distribution by this Space Internet have been gathered from NASA's Earth Science Enterprise (ESE), the Human Exploration and Development in Space (HEDS), and the Space Science Enterprise (SSE).

This presentation will address the evolving communications infrastructure for the Space Internetworking, the architectures within the infrastructure, and the elements that make up the architectures. The elements of architecture include the high data rate backbone, access to sensors, inter-spacecraft for formation flying, and proximity. From the architectures, technologies have been identified that have the most impact and are critical for the implementation of the architectures. We will show how deep networking environments created by the architectural elements will allow new ways of carrying out science in space.

Next Generation Satellite Systems and Services

R&D Plans for Japanese Next Generation Satellite Communications Systems

Naoto Kadowaki, Communications Research Laboratory, Japan

The Communications Research Laboratory (CRL) is the only national research organization for telecommunications technology in Japan. CRL is currently leading several R&D programs in the area of next generation satellite communications systems, which are outlined in this presentation. Specifically, the presentation describes the "Gigabit Internet Test Satellite" (working name), which will provide very high data rate transmission capability and Internet-friendly connectivity with wide area coverage. This satellite is planned as a key component of the NASDA-CRL "I-Space" project planned for launch in FY2005, based on advanced technology developed by CRL. This paper also summarizes other advanced satellite communications programs including ETS-VIII and Quasi-Zenith Satellite.

Technical Presentations

Next Generation Wireless

Next Generation Wireless

Wireless Networking: Current Status and Issues Facing the Next Generation

Magda El Zarki, University of California, Irvine

In this brief talk I will give a quick overview of the current status of wireless networking. I will then discuss 1) the motivation for, and 2) the ideas that inspired, the next generation and what some of the major problems are that must be overcome to make it happen. There are some successes, notably in the LAN domain, but the WAN arena is facing some hurdles that need to be overcome to make it a success.

Next Generation Wireless

Ad Hoc Networks – A New Communication Paradigm?

Zygmunt J. Haas, Wireless Networks Laboratory
School of Electrical and Computer Engineering
Cornell University

Ad-hoc Networks are network architectures that can be rapidly deployed and that do not rely on preexisting wireless communication infrastructure. Since the network diameter can be significantly larger than the transmission range of the network nodes, multihop routing is used. Due to mobility, the topology of a mobile ad-hoc network is continuously changing. Thus, self-reconfiguration capability is required. Finally, due to lack of centralized entities, all algorithms are fully distributed.

Although this technology has been well adopted by the military market, its use in the commercial sector is still uncertain. Few applications have been identified as potential areas in which ad hoc networks might be of interest. But we are yet to see any wide-scale deployment of this technology. Some exemplary applications include: communication when fixed infrastructure is unavailable (e.g., disaster recovery), sensor networks, extension of LAN environments (e.g., virtual classrooms), or as expansion of the cellular infrastructure (e.g., to alleviate "hot spots" or to increase total network capacity).

Of course, there are fundamental questions as to whether the ad hoc networking technology can be commercialized, due to its use of the multihop routing, and thus require some degree of user collaboration in establishing a network. Further areas of concern are reliability, manageability, and security of such a technology.

Challenges in the design of ad-hoc networks stem from the two main facts: the topology is unstable and there is no centrally available information. In this talk, after a short introduction to the ad hoc networks, I will discuss some general architectural design choices. We will then proceed with briefly exploring four different areas:

- Routing protocols (proactive vs. reactive, energy-efficient routing)
- MAC-layer ("to sense or not to sense, this is the question")
- Security
- Support for multimedia traffic (or how to route in the presence of frequent topological changes)

In concluding, I will give my perspective on the future of the ad hoc networking technology.

Next Generation Wireless

Implementation and Testbed Experiences in the Caterpillar Mobile Communications System Project

David B. Johnson, Department of Computer Science, Rice University

In 1997, while at Carnegie Mellon University, we started a three-year research program with Caterpillar Corporation to develop a global mobile wireless communication system, one that will support all mobile communications reliably and consolidate the needs for all business units in the construction and mining industries. Such a system will provide communication not only within a site, but will also provide remote access to machines and people from anywhere to anywhere. Possible applications of the system include future machine service support by providing direct access for field service technicians to an up-to-date database of service information; allowing dealers and technicians to do remote diagnosis or monitoring of a machine's condition or productivity; and deployment of intelligent applications and intelligent, cooperating machines. The project included extensive research in multi-hop wireless ad hoc networks, as well as integration of ad hoc networks with the Internet through Mobile IP. In this talk, I will describe some of our implementation and testbed experiences in the project with ad hoc networks and with Mobile IP and TCP over the NASA ACTS satellite.

Technical Presentations

Sensors and Sensor Networks

Sensors and Sensor Networks

Research Challenges in Embedded Networked Sensing

Deborah Estrin, University of California, Los Angeles/University of Southern California, Information Sciences Institute

Pervasive micro-sensing and actuation offers to revolutionize the way in which we understand and manage complex physical systems from airplane wings to complex ecosystems. Moreover, the capabilities for detailed physical monitoring and manipulation offer enormous opportunities for almost every scientific discipline. We investigate some of the architectural challenges posed by systems that are so massively distributed, physically coupled, wirelessly networked, and energy constrained.

Sensors and Sensor Networks

A Distributed Robotic Sensor Network for Tracking and Coverage

Gaurav S. Sukhatme, Robotic Embedded Systems Lab, Robotics Research Labs, University of Southern California

Mobile sensor networks are a promising direction for autonomous tracking and coverage applications. I describe a distributed architecture for a robotic sensor network to spatially organize itself in response to dynamic task requirements. The constituent nodes of the network are mobile robots capable of sensing and tracking targets. Our architecture is scalable, distributed and fault tolerant. This is borne out by recent experimental results in simulation and with a physical set of robots.

Sensors and Sensor Networks

A Remote Ecological Micro-Sensor Network (a.k.a. Pods)

Brian Chee, University of Hawaii,
Department of Information and Computer Sciences
Advanced Network Computing Lab

The project goal is to provide COTS-based microsensors for the study of endangered botanical species in various hard-to-study areas of the world. Pride in our national parks has forced this project to "hide" our sensors in plain site in order not to spoil the beauty of the park. We are building the communication network using a series of "pods." Each pod can collect instrument information and pass these data on to other pods. A pod is built around a power source, embedded computer, GPS receiver and wireless communications gear.

We also wanted to make the sensors cheap enough to enable eventual commercialization of the pods. This talk will show some of our really unique camouflage techniques, indicate how we have been solving our communications problems through cooperative research with MIT's Media lab, and discuss what our own efforts have been to cobble together new wireless routing protocols.

http://www.botany.hawaii.edu/pods

WORKSHOP 2001

Workshop Discussions 5

Workshop Discussions

5

Workshop Discussions

Seamless Integration Panel

Seamless Integration Panel

Panel Overview

David B. Johnson, Department of Computer Science, Rice University

"Seamless integration" is an idea that has been talked about among researchers, the press, and even some industry product groups for many years now, but this dream has not yet become a practical reality for everyday users. Today's wireless systems are fragmented in many directions, including incompatible, competing cellular standards, and a wireless LAN standard with a growing number of incompatible alternative physical layers. Satellite services still have limited capacity and high cost, and new LEO satellite constellations such as Iridium have not yet proven to be commercially viable. And promising protocol standards such as IETF Mobile IP for integrating these different physical systems at the network layer have still not yet been widely deployed. These are just some of the challenges facing practical seamless integration today. In this panel, we will attempt to answer the question of why we don't have seamless integration widely available today, and to identify what technology is likely best able to provide this goal.

Seamless Integration Panel

Panelist

John S. Baras, Director, Center for Satellite and Hybrid Communication Networks, University of Maryland, College Park

Hybrid satellite-terrestrial wireless infrastructures can be quickly deployed and can cover large number of scales in connectivity from a few meters to the whole Earth. They can now offer broadband connectivity to many at very affordable prices. In addition they serve very well in connecting to and from other terrestrial infrastructures. The bigger obstacles for interoperability in such infrastructures are: (a) lack of well defined and high quality standards; (b) the high degree of heterogeneity in both the physical media as well as in the type of information moved through these infrastructures. We will describe promising recent efforts in standards work particularly as it pertains to common air interface standards for satellites, wireless networks protocols and routing, and multicasting. We will also describe promising efforts and results in addressing the heterogeneity of these networks efficiently locally while still preserving end-to-end thinking and algorithms as much as possible.

Seamless Integration Panel

Panelist

J.J. Garcia Luna, University of California, Santa Cruz

Commercial internetwork technology has been oriented toward computer interconnection in relatively stable operational environments, which cannot adequately support many of the emerging civilian and military uses and interconnection of networks. A multihop packet-radio network (ad hoc network) is an ideal technology to establish an "instant communication infrastructure" in support of military operations and in disaster areas resulting from flood, earthquake, hurricane, or fire. Furthermore, ad hoc networks can be an attractive alternative as the last-mile Internet access method.

I will discuss technical problems for the seamless integration of a wireless internetwork to the rest of the Internet, which stem from the relatively small bandwidth available in ad hoc networks and the way in which communication media needs to be shared over a multihop network.

Seamless Integration Panel

Panelist

Dave Israel, NASA Goddard Space Flight Center

Since 1997, I have been lead engineer for several projects that used the NASA Tracking and Data Relay Satellite System (TDRSS) to connect remote locations to the Internet. These locations have included both the North and South Pole and various stops in between. There have been both technical and non-technical challenges involved with implementing these links. During my brief presentation, I'll provide a quick example of a particular mission and the challenges encountered.

Seamless Integration Panel

Panelist

David B. Johnson, Department of Computer Science, Rice University

A substantial amount of successful research has been done addressing seamless integration, including protocols like IETF Mobile IP, techniques such as wireless ad hoc networks, and new ideas such as software radios. However, none of this work has yet become commonly commercially available or been widely deployed and used. I believe that, unfortunately, the chief reason for this lack of availability or deployment is business: no one has yet figured out and implemented a way to make a lot of money from this. For example, most wireless use today is cellular voice service, and the public has shown only slight interest in new WAP services for accessing limited web content over cellular. However, this situation is poised to change, as the need for IP-based services and true access to the entire Web (unlike WAP) brings about an unstoppable force for change. IP is the technology that allows truly seamless integration and that supports the services and economies that will drive its realization. I will briefly describe an architecture that achieves this vision.

Seamless Integration Panel

Panelist

Wesley Kaplow, Qwest Communications

Qwest is in the process of exploring the creation of free-space optical wireless mesh metropolitan networks to help solve the problem of cost-effective broadband local access. The advantages of this approach include: no FCC regulations, no street permits and construction, high-capacity, fast deployment, and protocol transparency. It is Qwest's objective to provide 99.999% availability during all weather conditions for links up to 500 meters.

Qwest has recently installed such a link, capable of 622 Mbps, between the Qwest and National Science Foundation buildings in Arlington, Virginia.

Seamless Integration Panel

Panelist

Willie W. Lu, Principal Wireless Architect, Infineon/Siemens

"Convergence of Wireless Mobile and Access - Towards Beautiful Wireless Life"

The convergence of wireless mobile and access will be the next storm in communications. People using the same mobile terminal will be able to seamlessly connect to the wireless access networks as well as the mobile networks. This core technology will enable the complete solution of secured wireless mobile Internet applications. This hundreds-of-billion-dollar business will soon become a very hot topic in the wireless industry.

In this panel discussion, I will just present an architectural outline for the design of this converged broadband wireless core. More information will be available if interested.

Workshop Discussions

Breakout Discussions

Breakout Discussions

Charge to the Workshop Breakout Groups

Define "seamless integration" of mobile terrestrial and satellite networking.

What does it mean to users?

What does it mean technically?

Identify and describe the main technical challenges to achieving seamless integration.

What are the next steps? Give a roadmap showing:

What happens next?

What is being done already?

What is NOT being done?

Breakout Discussions

Breakout Discussion Results

BREAKOUT GROUP 1

Definition of Seamless integration

What does seamless integration mean to end users?

- Easy to use network and device – and the same anywhere
- Predictability of performance (know what to expect, have service level agreement)
- Good performance (latency, bandwidth, availability)
- Can determine behavior (can control trade-offs/compromises)
- Data integrity same as a standard wired system
- Small, portable, truly mobile
- Low power
- Security and privacy same as a standard wired system
- Low cost (bandwidth on demand, cost management)
- Rugged, cheap device (maybe same as a cell phone)
- End user "help system" (known accessible support)

What does seamless integration mean to system managers?

- Easy, quick to deploy
- Easy to configure (and reconfigure and upgrade)
- Easy to manage (e.g., remote management)
- Service support (customer support)
- Easy to diagnose (finger pointing)

What does seamless integration mean to developers?

- Developer only needs access to a rich API to get information from lower layers and to control lower layers

Main technical challenges to achieving seamless integration

- Interoperability of multiple standards
- Integration of routing for different types of networks
- Common air interface (for satellites and other types of networks)
- Scalability (even defining what it means! – number of nodes, amount of mobility, communication pattern, types of heterogeneous systems, terrain and obstacles to line of sight)
- Wireless-friendly applications (tolerate latency, variability, . . .)
- Wireless-friendly protocols (TCP, HTTP, . . .)
- Security (privacy, integrity, DOS, key generation and management, trust models and authentication, routing, . . .)
- Evaluation, measurement, simulation, validation
- True end-to-end solution vs. use of intermediate proxies
- Co-scheduling and resource reservation
- Multi-user interference, congestion, density
- Asymmetric routing and links, unidirectional routing and links
- Shortage of spectrum (and efficient use and reuse of)
- Multipoint communication (multicast, broadcast, reliable)
- MAC protocols for multi-hop ad hoc networks
- Cross-layer control, adaptation, and integration across application and protocol layers
- Billing (smart cards, accounting)
- Quality of service
- Energy-efficient protocols (routing, MAC, . . .)

Breakout Discussions

Breakout Discussion Results

BREAKOUT GROUP 1 cont.

Roadmap

What's being done already?

- IETF (Internet Engineering Task Force) activities:
  - IETF MANET (Mobile Ad hoc Networks) routing standard: DSR and AODV Experimental RFCs (expect standard within about 5 years)
  - IETF Mobile IPv6 standard (expect standard within about 1 year)
  - Integration between Mobile IP and MANET routing is critical (expect standard within about 5 years)
  - IETF UDLR (UniDirectional Link Routing) RFC
  - IETF PILC (Performance Implications of Link Characteristics) working group: Informational RFCs
  - IETF Layered IPSec
  - IETF standard for TCP over wireless (within 3 years)
- IRTF reliable multicast group (not sure if group is addressing wireless yet)
- New consumer stationary two-way satellite services available either now or soon (StarBand, DIRECWAY, WildBlue, SPACEWAY, Astrolink, ICO)
- Some commercial test markets of fixed wireless ad hoc (Nokia, DoCoMo, Siemens/ Infineon, Nortel)
- Internet-friendly satellite gateways (some standards, most are proprietary)
- Distributed key generation and management, but not enough work on distributed trust and authentication
- Web transcoding proxies (AvantGo, . . .)
- Integration of multimedia over IP over satellite
- Work on defining and measuring quality of service
- Service and content redirection (Akamai, Inktomi, . . .)
- Commercial Internet to and from airplanes
- Wide use of GPS (location-based services, clock synchronization, routing, …)
- Lots of work on wireless-friendly TCP and HTTP

What happens next?

- Common radio API
- Software radio
- Affordable directional antennas
- Portable/mobile consumer two-way satellite

What's NOT being done?

- Major large-scale integrated wireless testbeds
- Validation of large, complex wireless simulation and analytical models
- Human interface standards (keyboard or pen or . . .?)
- Unified cross-layer control, adaptation, and integration across protocol and application layers
- Autonomous intelligent management of large integrated (heterogeneous) wireless systems
- Standards for energy-efficient protocols for ad hoc and sensor networks (routing, MAC, . . .)

Breakout Discussions

Breakout Discussion Results

BREAKOUT GROUP 2

Definition of Seamless Integration

This breakout group began by attempting to parse the seamless integration problem into its essential parts. The group decided on a simple four-part model of networking suitable for this purpose:

End user: This may be a human being or an intelligent agent acting as an end user.

Appliance/application: This is the hardware and software box that represents the end user to the network.

Network edge interface: This is the multilayer access link from the appliance and application to the underlying network.

Network backbone and feeder networks: This is the underlying network, including both the feeder networks such as satellite and wireless as well as the fiber wavelength core.

Based on this four-part model, the group discussed what seamless integration would mean to each part. Overall, seamless integration is considered to be a relative rather than an absolute term, defined as the abstraction of network numbers to user meaningful names, and the provision of smooth and efficient interfaces to hide the implementation of services provided by the underlying network. The end user should not need to know the details of the appliances, applications and network edge interfaces that are used to reach the underlying network. The end user also should not need to know anything about the network backbone, which is seen solely as a source of bandwidth on demand.

Technical challenges

END USER

Meaning of seamless integration from the end-user perspective

- Simple user interface: human doesn't have to understand anything about the network
- Transparent
- Unobtrusive: user isn't aware there is a network out there (the network services are available anywhere, anytime, to anyone authorized to access the services)
- Ubiquitous access
- Trusted, secure, reliable

Challenges to achieving seamless integration

- Security
- Ease of use/ergonomics
- Regulatory, economic, and technical challenges to ubiquitous access

Solutions

- Provide multiple layers of security, based on user needs (e.g., normal users need only a small number of simple security services; military, medical, financial users need many more and deeper security services)
- Develop more user friendly means of recognizing user inputs (e.g., voice recognition, Blue Tooth connected keyboards if needed)
- Do a better, more user friendly job of identifying the individual (e.g., thumbprint, retina scan, or at worst a smart wireless card carried by the individual)
- Give user the option to do risk analysis/ risk assessment
- Give user the ability to pay for services, as and when needed

Breakout Discussions

Breakout Discussion Results

BREAKOUT GROUP 2 cont.

APPLIANCES AND APPLICATIONS

Meaning of seamless integration from appliance perspective

- Appliance should maintain a user profile (e.g., preferred interfaces, most-used service features, preferred data rates, bandwidth needed on demand or scheduled, what costs are acceptable)
- Appliance should have a simple interface that accommodates a range of appliance features and performance
- Interface should be able to adjust data rate, as needed
- Interface should be able to schedule appliance utilization, as needed

Meaning of seamless integration from application perspective

- Application should be smart
- Application should be aware of context, in terms of the user, platform, and network
- Application should be aware of network properties, such as latency, bandwidth, loss characteristics
- Application should know what services are available and how to access them
- Service broker should be provided and range of interfaces to broker should exist, from simple to professional user

Challenges to achieving seamless integration

- Power limitations for handheld devices
- Information recognition, e.g., voice recognition
- Adaptive applications
- Achieving context awareness
- Agreement on definition of things that can be requested from the network
- Build in ease of use
- Trust, security; how to identify the end user

Solutions

- Standardization (e.g., interfaces)
- Better models of Service Level Agreements
- Common set of metrics associated with models (what do we ask for and what do we get?)
- Interface architecture optimization (gateway)
  - Where do you put resources and how do you get to them?
  - Changes as interface and processes change
- Balanced system architecture (characteristics of the resources)
  - Network equivalent of impedance matching
  - How do you balance the architecture when the environment constantly changes?

NETWORK EDGE INTERFACE

The network edge is an agent or gateway between the user and the network. It includes interfaces to appliances and applications on the user side, and the edge interface to the first Internet Service Provider on the network side.

Meaning of seamless integration from the network-edge perspective

- Roam-ability, nomadicity
- Interface into the network should be negotiable—there is a difference between portability and mobility, IPv4/IPv6
  - Services
  - User-defined priorities (e.g., cost management)
- Ideal goal: Network should be self organizing, giving each edge device non-blocking, completely scalable access to the network backbone.

Breakout Discussions

Breakout Discussion Results

BREAKOUT GROUP 2 cont.

- Edge device should be an agent of backbone (e.g., knows about about network services, brokers access to network services, covers multiple layers, can access expert agents within network if there are any problems)
- Network should be reconfigurable (configured to use only the resources you need; this would conserve energy)
- Network edge facilities need to be dynamic
  - Wake up when you need them
  - Provide a customized, one-time path when needed

Challenges to achieving seamless integration

- Providing bandwidth on demand (dynamic bandwidth allocation)
- Lack of unified picture including more details about applications and higher layers
- Changing domains involves a lot of complexity and introduces a lot of problems (e.g., security)
- Incompatible systems depending on geography

Solutions

- Develop taxonomy to describe the network edge interface
- Examine hand-off methods and protocols
- Develop common air interface standards for satellites
- Network equivalent of software radio (e.g., baseband, IF, application)

NETWORK BACKBONE AND FEEDER NETWORKS

The network includes both the optical backbone and the feeder networks. Wireless technology is a feeder technology. As you move from the edge to the core of the network, performance increases and variability/flexibility decreases.

Meaning of seamless integration from the network perspective

- Network should not need to be intelligent about the services provided to the end user
- The user should not have to know how the network is implemented
- The network backbone should be scalable. (Switches are the bottleneck now. Maybe eliminate switches in the future.)
- The network backbone should appear to be homogeneous

Challenges to achieving seamless integration

- Need a more adaptable backbone and more adaptive protocols
- Providing quick access to the backbone; how can the number of hops between the user/ application and the backbone be reduced?

Solutions

- Adaptability of protocols to various interfaces
- Establish a taxonomy for feeder networks
- Be able to translate requirements between the backbone and whatever services are available to the user (seamlessly) (e.g., QoS, security, cost, attributes)
- Mobile (e.g., GSM) should be the least preferred solution to be offered as a feeder network (because mobile will always provide lower bandwidth at higher cost with fewer implementation and deployment options than fixed wireless or fiber)
- Need model for scalable routing
- Generalized Multiprotocol Label Switching

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APPENDICES 6

Appendices

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TECHNICAL PRESENTATIONS

Next Generation Satellite Systems and Services

A Brief History of Satellite / Terrestrial Net work Interoperability Studies
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Architectures and Protocols for Next Generation Satellite Networks
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Space Networking: Enabling NASA's 2010 Visions for Science and Exploration
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R&D Plans for Japanese Next Generation Satellite Communications Systems
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Next Generation Wireless

Wireless Networking: Current Status and Issues Facing the Next Generation
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Ad Hoc Networks—A New Communication Paradigm?
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Next Generation Wireless cont.

Implementation and Testbed Experiences in the Caterpillar Mobile Communications System Project
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Sensors and Sensor Networks

Research Challenges in Embedded Networked Sensing
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A Distributed Robotic Sensor Network for Tracking and Coverage
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A Remote Ecological Micro-Sensor Network (a.k.a. Pods)
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