

An Integrated Coastal Wireless Network

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LONG-TERM GOALS

The goal of this study is to define a wireless network architecture that can be deployed to enable contiguous coastal area network coverage for scientific, commercial, and homeland security (e.g. Coast Guard) applications within the United States Exclusive Economic Zone (EEZ), in a manner that is flexible, manageable, and affordable. As described in Reference 1, we present the architectural requirements of such a system, delineate suitable technologies that will achieve such a vision, and provide a plan to demonstrate the concept.

OBJECTIVES

Initially, user requirements (i.e. functional requirements) for the United States Coastal Area Network (U-SCAN) were determined. These requirements encompassed all three intended domains of use: scientific, commercial, and homeland security, as depicted in Figure 1.

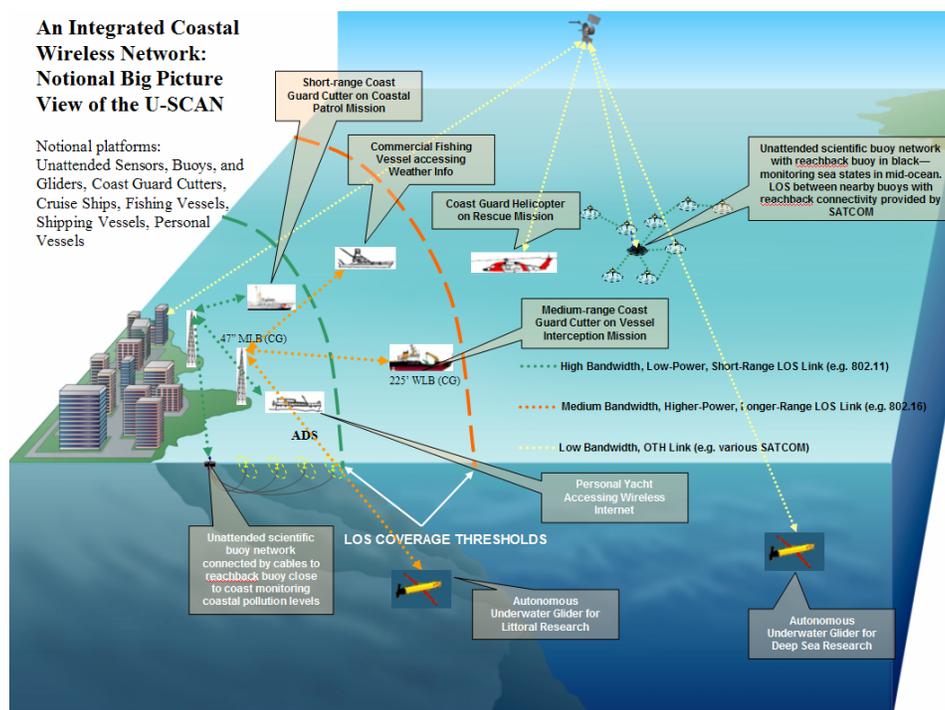


Figure 1 A Vision of the Eventual Multi-purpose U-SCAN

A technology candidate catalog was delineated that summarizes the capabilities and drawbacks of envisioned communications systems, focusing on technologies commercially available within the timeframe of interest. An appropriate subset of technology candidates was chosen for detailed

architectural consideration based upon an initial analysis of all technology candidates and an assessment of how well they met the determined user requirements. A secondary down-selection resulted in a select set of technology candidates deemed most promising. These candidates and their associated power requirements, cost estimates, and architecture integration issues were described in detail in the final architecture description in Reference 6 along with some notional scenarios. A technology demonstration and transition plan were also provided in this reference.

APPROACH AND WORK PLAN

The high-level work plan for the first year of this project is presented in Figure 2. Initially, high-level functional requirements were determined, including: 1) approximate user applications along with corresponding data packages and performance requirements, and 2) notional operational scenarios for the U-SCAN. Requirements of the scientific community were determined by Drs. Scott Glenn and Oscar Schofield of Rutgers University, who maintain a coastal network for Rutgers University’s oceanographic research applications. Potential Coast Guard requirements were determined by JHU/APL through coordination with Coast Guard representatives. Perceived commercial requirements were determined by the composite team. The JHU/APL portion of the team translated these functional user requirements into technical requirements. These two requirement sets are isolated from one another in order to prevent network technology constraints from introducing bias into the requirements of the user.

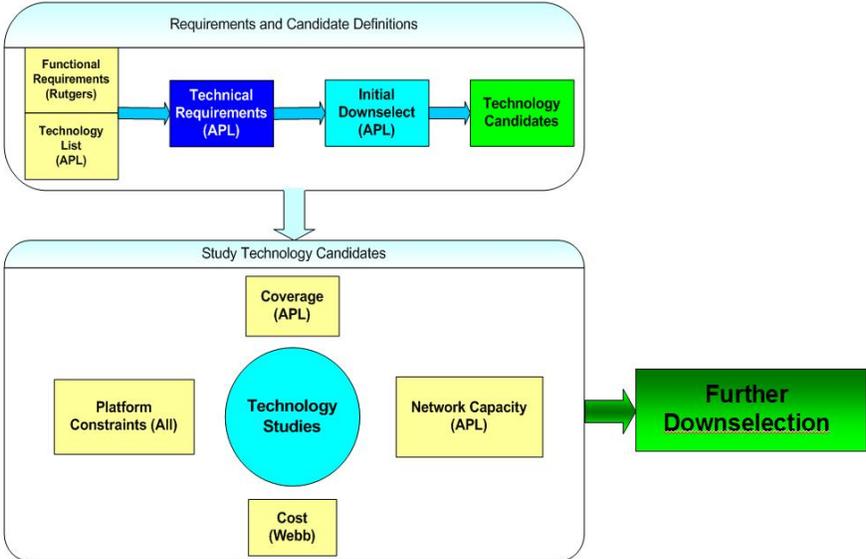


Figure 2 Year One Project Technical Approach Overview

Available WLAN and over-the-horizon (OTH) communications technologies were assessed for their overall applicability against the requirements by William Kasch, Jack Burbank, Harold Zheng, and Brian Haberman of JHU/APL. This assessment began with an initial cataloging and high-level characterization of commercially-available technologies (represented as the 'Technology List' of Figure 1). These technologies were then judged against user requirements and a corresponding down-selection occurred. Remaining candidate technologies underwent a more rigorous evaluation.

Performance studies were conducted to determine the viability of those remaining technology candidates to be combined in an integrated architecture. Studies focusing on coverage, platform

constraints, and network capacity were performed by the JHU/APL team members. The results of these studies were used to perform another down-selection. The remaining 'best-of-breed' technology candidates constituted the candidate set at the end of year one, and underwent a second set of technical studies during year 2, illustrated in Figure 3. A cost study was performed by JHU/APL with consultation from Clayton Jones of Webb Research, whom has conceived and built a variety of oceanic scientific platforms including those used by Rutgers University.

Architecture integration studies were performed primarily by JHU/APL participants in the study with consultation to the team members from Rutgers and Webb Research. Here, four areas of interest for study were identified: 1) routing and Quality-of-Service (QoS), 2) network management, 3) security, and 4) interference. The routing and QoS study focused on methods of classification and efficient routing of packets through the envisioned variable U-SCAN network topology. The network management study identified network management techniques and approaches that effectively improve ease-of-use and promote automation to minimize maintenance cost and network complexity. The security study identified suitable security policies, models, and mechanisms, along with assessing the impacts of such security mechanisms on U-SCAN performance. It was found that in an environment where commercial, scientific, and homeland security users operate concurrently, many different levels of security will be required to meet user needs. Both the network management and security studies focused on commercial best practices and commercially-deemed viable solutions. Finally, an interference study was conducted to determine the performance impacts of potential U-SCAN technologies have on neighboring communications systems, and vice-versa, in order to ensure effective coexistence of technologies and adherence to US and/or International radio frequency (RF) regulations.

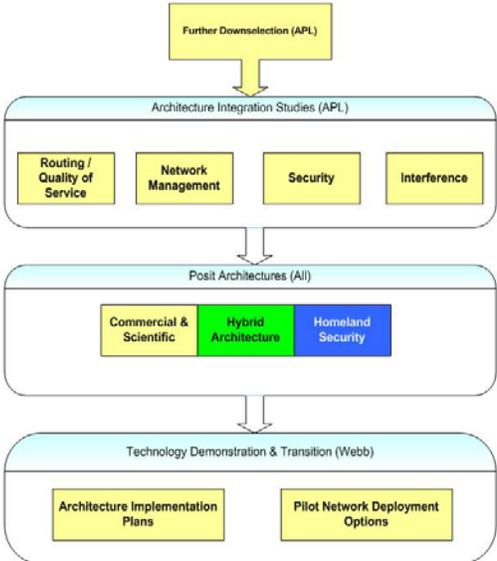


Figure 3 Year Two Project Technical Approach Overview

Finally, technology demonstration concepts were conceived by JHU/APL with consultation from Webb Research that identified and addressed implementation issues, technology transition strategies, and provided risk mitigation strategies.

WORK COMPLETED

The final report (Reference 6) published in April 2006 provided a final vision for the U-SCAN architecture as resulted from the studies conducted for this project.

RESULTS

The JHU/APL-led study provides recommendations to NOPP regarding potential network architectures and technologies that could provide the desired capability. This study has focused its attention on standardized commercial technologies in order to facilitate a cost-effective architecture. This study has concluded that an Internet Protocol (IP)-based general purpose network can likely be realized in a cost-effective manner with an underlying radio architecture consists of two components: line-of-sight (LOS) radio and beyond-LOS (BLOS) satellite connectivity. The recommended hybrid radio architecture would be based on the Institute of Electrical and Electronics Engineering (IEEE) 802.16 and 802.11 technology families, which this study concludes can be realized in an affordable architecture that allows for evolution and upgrade. The study recommends that either Inmarsat or Intelsat be employed as the BLOS technology. This study has divided the U-SCAN into three distinct domains: fixed shore-based, fixed sea-based, and mobile. This study has proposed a logical structure of the overall network to enable extensibility and expandability across the entire United States coastal area, and has provided recommendations on mechanisms and models for IP-routing, Quality-of-Service (QoS) provisioning to support a diverse application set (e.g. multimedia applications), network management approaches, and network security approaches.

IMPACT/APPLICATIONS

National Security

An effective U-SCAN architecture could provide high-speed network access to Coast Guard vessels within the EEZ coverage area. Such a network would prove invaluable to Coast Guard professionals who may need to exchange near-real-time imagery, video, and voice traffic to enable more effective coastal surveillance and foreign vessel interception and/or inspection. Furthermore, U-SCAN backhaul connections into other homeland security agencies could enable more effective information sharing between the Coast Guard and such agencies for an overall improved level of homeland security.

Economic Development

Commercial vessels that may have access to an Internet best-effort-type network provided by the U-SCAN may improve bottom lines to their respective companies because they could connect directly to their corporate networks at high speed while in or near ports of entry. Connection to the corporate network enables passengers of the commercial vessels to remain in contact with their company, improving corporate efficiency. Cruise ships that provide high-speed Internet access to their passengers may charge a fee for such a service and could further improve profit margins. Likewise, personal vessels that are outfitted with U-SCAN equipment could be charged fees for such access that could be used to maintain and improve the U-SCAN network. All these possibilities may provide additional jobs related to maintenance and development, and release more corporate capital investment because of improved efficiency.

Quality of Life

Quality of life is expected to improve dramatically for commercial and personal users who may be able to access the near-real-time Internet. Improved efficiency for corporations results in more time available for employees to enjoy other aspects of life. Furthermore, scientific experiments that utilize the U-SCAN may provide insight into weather phenomena that may improve the ability to predict and warn terrestrial areas of impending weather, thus reducing risk to life and land.

Science Education and Communication

The U-SCAN is expected to be an integral part of scientific monitoring and oceanography. By providing the network infrastructure to cover the entire EEZ of the U.S. coast, various scientific sensors and vessels could be deployed to monitor ocean activity and enable many possibilities otherwise unavailable today for scientific experimentation and data collection. Scientific experiments could provide insight into ocean behavior during various natural phenomena including hurricanes, tsunamis, and earthquakes, and has great potential to benefit society through inherent improved data collection capabilities.

TRANSITIONS

National Security

It is expected that an architecture such as the U-SCAN could be employed for many National Security applications, including surveillance, voice, and video.

Science Education and Communication

With Rutgers University on the U-SCAN project, science education and outreach is achieved at a variety of educational levels. The Rutgers University Coastal Ocean Observation Laboratory (RU COOL) is part of the Institute of Marine and Coastal Sciences and provides not only undergraduate/graduate education but also outreach to K-12 students. U-SCAN is one of the projects in the portfolio that provide educational benefits in oceanographic science and technology.

RELATED PROJECTS

There are other projects relating to the objective of this project; the most significantly related projects are outlined below with an emphasis on their communications approach. This listing is not exhaustive as there are many small initiatives to extend the use of wireless technology.

- **NEPTUNE:** The North-East Pacific Time-series Undersea Networked Experiments (NEPTUNE) project is to design an observatory infrastructure for the Pacific Northwest and is a partnership of the University of Washington, University of Victoria and Woods Hole Oceanographic Institution. The system's fiber optic cabling provides both power and communications distributed over 1000 km. Due to the capabilities of fiber optics, the system can deliver large data rates of 10 Gbps and network directly to the Internet which is a fundamental difference from the U-SCAN project, which has a wireless focus.

- MARS and VENUS: The Monterey Accelerated Research System (MARS) and the Victoria Experimental Network Under the Sea (VENUS) are initiatives to link oceanographic instruments with cables, similar to the NEPTUNE project described above.
- VeriLAN Broadband Wireless: This is part of an initiative in the Oregon area to provide high-speed internet to residents on the coastal areas where these capabilities are lacking. In 2003, VeriLAN announced the deployment of a beta test infrastructure of about 100 square miles. This system utilizes a primary technology of the U-SCAN project (802.16). However, it is focused on land-based users, and relies on the stability of fixed sites to use directional antennas. In contrast, the U-SCAN project aims to create an infrastructure extending further into the ocean area and will need to support platforms without inherent stability. There are many commercial ventures similar to this (e.g., Coastal Broadband in GA, Midcoast Internet Solutions in ME).
- High Performance Wireless Research and Education Network (HPWREN): This is an NSF-sponsored initiative to create a wide-area wireless network in southern CA for a variety of uses. It is a multi-institutional initiative of UC San Diego and includes the San Diego Supercomputer Center and the Scripps Institution of Oceanography. HPWREN has supported oceanography applications and demonstrated a link at a range of 72 miles. It has been used to support shallow water deployment of data acquisition systems studying waves and erosion using IEEE 802.11b.
- LOOKING: The Laboratory for the Ocean Observatory Knowledge Integration Grid (LOOKING) is sponsored by NSF and is a collaboration of the University of Washington, UCSD and others to develop and information infrastructure in the west coast of the US, Mexico and Canada. The project deals with not only communications but sensors, web services and other aspects of an information infrastructure.

REFERENCES

- [1] R.A. Nichols, et al., "An Integrated Wireless Coastal Communications Network," JHU/APL Proposal No. AD-25495, Pursuant to the ONR BAA Announcement #03-014.
- [2] R.A. Nichols, et al., "An Integrated Coastal Communications Network: Functional Requirements," JHU/APL Technical Memorandum VIC-05-006.
- [3] W.T. Kasch, et al., "An Integrated Coastal Communications Network: Technology Descriptions," JHU/APL Technical Memorandum VIC-05-007.
- [4] W.T. Kasch, "An Integrated Coastal Communications Network: Platforms and Geometric Considerations," JHU/APL Technical Memorandum VIC-05-008.
- [5] J.L. Burbank, "An Integrated Coastal Communications Network: Coverage Study Plan," JHU/APL Technical Memorandum VIC-05-009.
- [6] J.L. Burbank, et al., "An Integrated Coastal Wireless Communications Network," JHU/APL Final Report to NOPP Program Office, April 2006.