Wireless Networking and Communications Technologies at APL: Guest Editor's Introduction

Jack L. Burbank

ABSTRACT

Wireless communications and networking technologies have drastically changed the way we live. An explosion of innovation over the past two decades has resulted in wireless networking capabilities that have fundamentally changed the way we create, share, and use information. Combined with advances in computing and networking technology, the wireless Internet ushered into reality the information age predicted long ago. This information era has undeniable effects on global socioeconomic and cultural conditions. These effects have had a profound impact on the operations of governments and military forces. Timely and reliable access to information is key to the success of virtually all government and military functions. Having effective communications and networking solutions is critical to mission success, and over the coming decades this requirement is expected to become increasingly important. Consequently, researchers at the Johns Hopkins University Applied Physics Laboratory (APL) will continue developing wireless communications and networking ideas, concepts, and solutions that are more efficient, effective, and affordable. This issue of the Johns Hopkins APL Technical Digest highlights some of the recent work by APL researchers in the areas of wireless communications and networking. Although it provides only a small sample of the wide range of work being done at APL, this issue presents articles on key topics such as leveraging commercial wireless technology in affordable military solutions, the evolution of security within the Internet community, satellite communications, high-capacity optical technologies, and network management.

INTRODUCTION

The Johns Hopkins University Applied Physics Laboratory (APL) was founded in 1942 to aid a country at war. The world has fundamentally changed since APL's formation, but to this day, the founding principle of service to the country continues to act as the Lab's compass. Because of its commitment to sponsors and the success of their missions, APL strives to innovate in the scientific fields that are critical to success.

Effective communication has always been critically important, but this is especially true in modern times. The computer revolution, the Internet revolution, and most recently the wireless revolution have profoundly

changed the world. Nowhere is this reality more apparent than in governments and military forces, which rely on a sophisticated global network infrastructure with cutting-edge wireless technologies providing connectivity to globally deployed forces and personnel.

APL has conducted communications research for decades. Early research primarily focused on improving the efficiency and performance of point-to-point terrestrial radios and satellite communications technologies. The importance of that work has not diminished. Innovations in antenna technology, waveform efficiency, spectrum and network management, and satellite communications continue to be important topics and are areas of active research. However, over the past two decades, APL has expanded its work in the communications and networking field to encompass Internet protocol (IP)-based networking and the technical challenges associated with deploying a global network infrastructure. Researchers at APL remain committed to ensuring that government and military end users have reliable, effective, and affordable connectivity to reach back to networked assets. APL researchers are committed to innovation to ensure that global network infrastructure can be effectively and affordably realized.

The role of APL in the wireless communications and networking technology landscape is multifaceted and depends on current and anticipated sponsor needs within a particular technology area. Figure 1 depicts examples of APL roles and contributions in this domain.

The exact role of APL in the technology development process varies greatly depending on sponsor needs and technology maturation. In some cases, APL is involved with technology development from the ground up, developing an initial concept and shepherding that concept to a deployed capability. In this capacity, APL has a rich history in all of the various roles and activities depicted in Fig. 1, including initial concept development, prototype development, concept of operations and policy development, and testing and evaluation.

In other cases, APL serves as a trusted agent by evaluating existing technology solutions or identifying how to best use existing capabilities. In this role, APL may conduct laboratory-based bench-top assessments of a technology or field exercises to assess the performance of a technology in an operationally representative environment. APL has a long history of serving in this role, having conducted highly complex field assessments for a wide range of sponsors and technologies.

In many cases, APL conducts basic research into topics such as antenna technology, new modulation and coding approaches, network routing approaches, and network security approaches. In other cases, APL conducts research to understand phenomenon that impact network performance (e.g., wireless propagation).

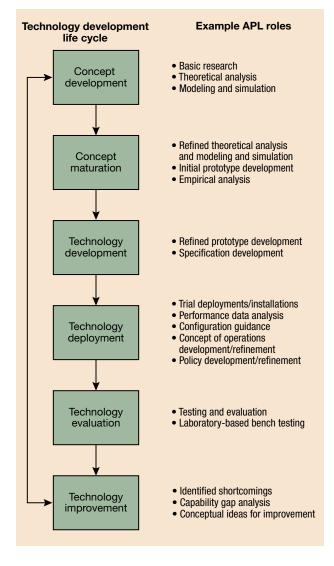Regardless of where APL's involvement begins in the technology life cycle depicted in Fig. 1, APL's goal

Figure 1. Technology development life cycle and example APL roles and contributions.

in this process is to perform any necessary actions to satisfy sponsor needs and provide the best capabilities possible to the warfighter. This issue of the *Johns Hopkins APL Technical Digest* describes some of the work being conducted by APL researchers to ensure sponsors are equipped with the best possible wireless networking solutions. The issue includes seven articles that cover a diverse set of relevant topics. In addition to the current issue, numerous past issues have highlighted APL's work in this domain (e.g., Volume 30, Issue 2, 2011; and Volume 25, Issue 4, 2004). Furthermore, APL researchers consistently publish and present their work in a variety of venues, including the Institute of Electrical and Electronics Engineers (IEEE) Military Communications (MILCOM) Conference, the IEEE Global Communications Conference (GLOBECOM), *IEEE Communications Magazine*, and the journal *IEEE Transactions on Wireless Communications*. In addition to contributing

to the scholarly literature, APL experts also contribute to various standards bodies including those of IEEE, the Internet Engineering Task Force (IETF), and the International Telecommunication Union (ITU).

THE ARTICLES

Commercial wireless networking technologies have rapidly evolved over the past two decades and are superior to their military counterparts in numerous ways. However, these technologies were not designed for the rigorous use cases of government and military scenarios and may suffer unintended performance consequences. The first two articles in this issue describe the application of commercial technologies to solutions in the government and military problem spaces.

The first article, by Andrusenko et al., examines some of the key trends in commercial wireless networking technology and how they can be brought to bear to provide effective and affordable solutions to government and military problems. The article also cautions that irresponsible application of commercial technologies can potentially degrade mission effectiveness and that great care must be taken to manage potential risks while harvesting the enormous potential benefits. The article also illustrates some of the APL's scientific and technology development contributions to both academic forums and commercial standards bodies.

The second article, by Haberman, describes an ongoing revolution in Internet security and the enormous momentum that has built behind a significant re-architecting of the concepts, approaches, and technologies that secure today's commercial IP networks. It is extremely important for researchers to understand and, when possible, to shape and influence these trends because these developments will influence the technologies that will be available when building future government and military network solutions. The article highlights many of the key changes commercial standards bodies are considering and describes the benefits and drawbacks of these various changes. The article also discusses how these changes have numerous potential benefits to network users concerned about privacy but may also have negative consequences for network operators and users who have built use models on older, less-secure protocol designs.

In the third article, Bamberger et al. highlight the critical importance of systems engineering methodology in the effective development of complex systems. The article discusses model-based systems engineering methods and their potential ability to significantly impact the affordability of complex systems over their life cycles. The article then presents an APL-developed model-based systems engineering methodology and discusses it within the context of a netted intelligence, surveillance, and reconnaissance concept.

Effective satellite communications (SATCOM) remain critical to the success of government and military operations. Isolated naval vessels heavily depend on SATCOM for communications. Ground forces that deploy in regions without preexisting infrastructure rely heavily on SATCOM for reachback services. Because of this, researchers at APL continue to build on decades of experience to improve the SATCOM capabilities available for their sponsors. Two articles in this issue focus on this subject.

The article by Cuevas and Weerackody examines the subject of mobile SATCOM and the technical and regulatory challenges associated with mobile SATCOM Earth stations. This technology is critical to the numerous government and military communities that depend on mobile SATCOM. The article examines small-aperture SATCOM terminals on moving platforms and the need to influence and effect changes in relevant international regulations (in forums such as the ITU) to enable such concepts of operation.

The article by Gündüzhan and Brown focuses on narrowband SATCOM and its challenges for the DoD, as well as potential options for next-generation systems. It discusses several emerging technological enablers and recent advances in SATCOM services that may prove invaluable in assisting the DoD community to keep pace with growing user needs for SATCOM capability by improving spectral efficiency and service offerings. The article also discusses the challenges associated with improving resilience against kinetic, electronic, and cyber attacks and proposes numerous technical concepts that can contribute to the solutions to these problems while also potentially reducing the size and cost of narrowband SATCOM terminals.

The sixth article, by McKenna et al., describes the combination of millimeter-wave and photonic technologies in high-data-rate communications systems. The article shows how the benefits of each technology, through their combination, can be leveraged to develop systems more capable than either technology alone could achieve. Such innovations are critical in supporting very-high-data-rate applications (e.g., streaming video) or in supporting wireless data aggregation (e.g., wireless backbone connectivity).

In the final article, Schneider discusses the challenges of large-scale network management. He notes that many disparate and dispersed network management systems are unable to directly share network information, instead relying on person-to-person communications. Furthermore, each system uses its own information semantics, making it difficult to share electronic information and inhibiting the ability to perform network management across these disparate networks. As a solution to improve management interoperability of these disparate systems, the article describes a concept for the use of ontology-based techniques widely used in the commercial domain.

The articles in this issue represent only a small fraction of the wireless networking research and development taking place at APL, but this sampling gives readers insight into the contributions APL researchers are making. The authors, the *Digest* staff, and I hope you enjoy the articles and find that they are useful in helping you to understand this complex landscape and the challenges facing the entire government and military communications community. APL's core principle remains service to the country, and it will continue to conduct research and development and innovate to ensure that the most effective and affordable solutions possible are available for the warfighter.

THE AUTHOR

Jack L. Burbank is the Assistant Group Supervisor of the Tactical Wireless Systems Group and a member of the Principal Professional Staff at APL. His recent work is in the areas of wireless network security, cellular communications, and cognitive networking. He is an associate technical editor of *IEEE Communications Magazine*, the author of books on network modeling and simulation and wireless networking, and the editor of the Wiley-IEEE Press book series on IEEE standards. He teaches courses on networking and wireless networking in the Johns Hopkins University Engineering for Professionals program and is a senior member of the IEEE and the American Society for Engineering Education. His e-mail address is jack.burbank@jhuapl.edu.