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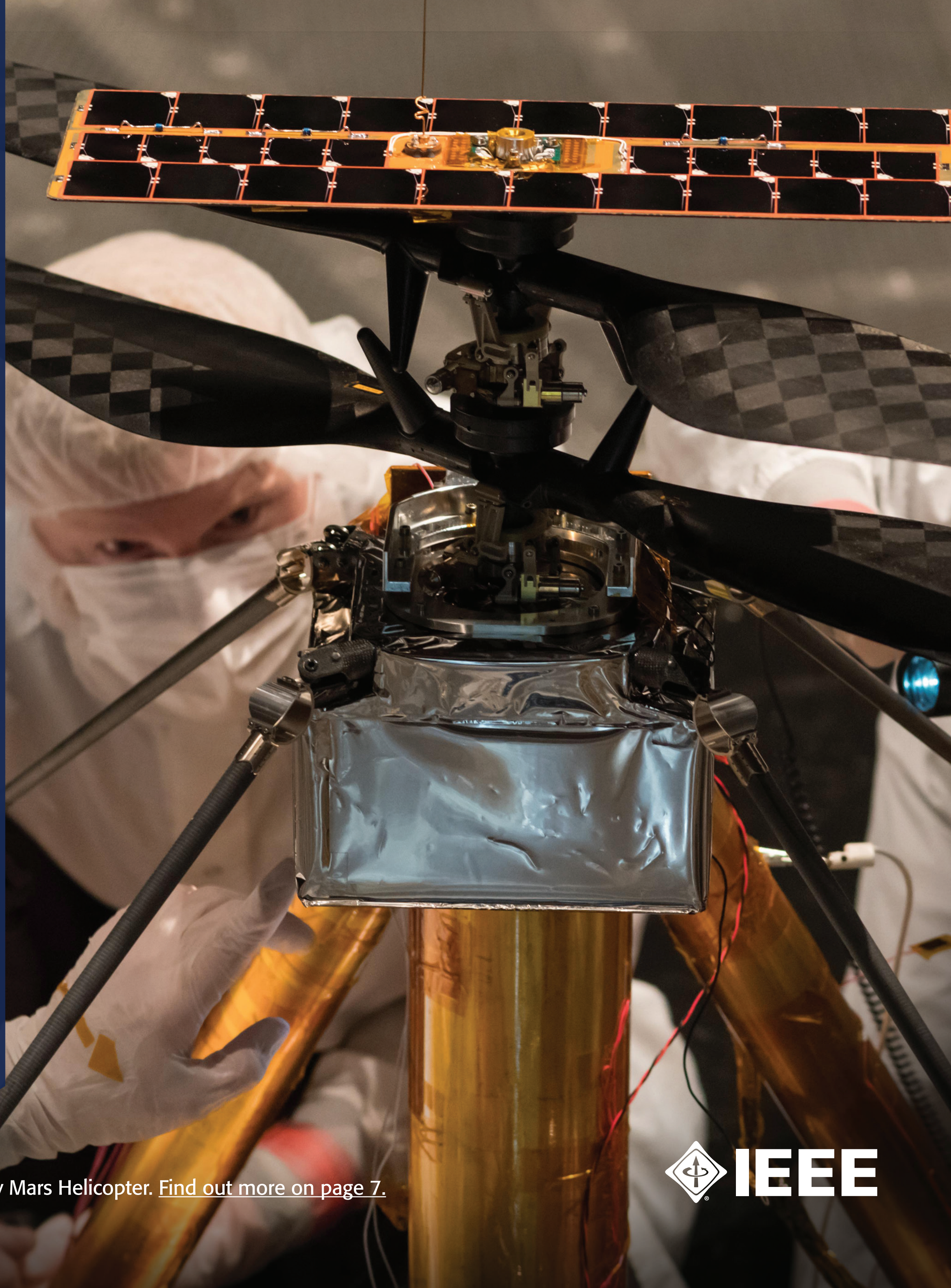
THE BRIDGE

The Magazine of IEEE-Eta Kappa Nu



TRENDS IN
Communication Networks

Advances in *Accessibility, Connectivity,* and *Quality.*

Quality-of-Service Architecture for Cloud Computing Networking

Analyzing Service Mesh Performance

Facilitating Satellite-Airborne-Balloon-Terrestrial Integration for Dynamic and Infrastructure-less Networks

Happy Founders Day!
How Will You Celebrate?

IEEE-Eta Kappa Nu

A view of NASA's Ingenuity Mars Helicopter. Find out more on page 7.

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As the Honor Society of IEEE, IEEE-Eta Kappa Nu provides opportunities to promote and encourage outstanding students, educators and members.

Visit our new website to view the awards programs, awards committees, list of past winners, nomination criteria and deadlines.

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Recognizes members who have devoted years of service and lifetime contributions to Eta Kappa Nu (or IEEE-HKN), resulting in significant benefits to all of the Society's members.
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Recognizes chapters for excellence in activities and service at the department, university and community levels. The award is based on the content contained in their Annual Chapter Report for the preceding academic year.
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Presented annually to an exceptional young engineer who has demonstrated significant contributions early in their professional career.
(Deadline: Monday after 30 April)

IEEE-HKN ASAD M. MADNI OUTSTANDING TECHNICAL ACHIEVEMENT AND EXCELLENCE AWARD

Presented annually to a practitioner in the IEEE technical fields of interest who has distinguished himself or herself through an invention, development or innovation that has had worldwide impact.
(Deadline: Monday after 30 April)

IEEE-Eta Kappa Nu (IEEE-HKN) was founded by Maurice L. Carr at the University of Illinois at Urbana- Champaign on 28 October 1904, to encourage excellence in education for the benefit of the public. IEEE-HKN fosters excellence by recognizing those students and professionals who have conferred honor upon engineering education through distinguished scholarship, activities, leadership, and exemplary character as students in electrical or computer engineering, or by their professional attainments. *THE BRIDGE* is the official publication of IEEE-HKN. Ideas and opinions expressed in *THE BRIDGE* are those of the individuals and do not necessarily represent the views of IEEE-HKN, the Board of Governors, or the magazine staff.

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THE BRIDGE

The Magazine of IEEE-Eta Kappa Nu

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Gamma Theta Chapter

THE BRIDGE, October 2021 Letter from the Editors-in-Chief

Dear IEEE-Eta Kappa Nu Members and Friends,

The theme of this issue of *THE BRIDGE* magazine is "Trends in Communication Networks," and the content reflects some of the current engineering problems and work in communication technologies. Our features discuss methods to prioritize internet traffic, to increase functionality, and to create dynamic network capability. Such improvements to internet traffic engineering, internet performance, and internet access are examples of continued expansion of communication technologies. Our cover shows NASA's Ingenuity Mars helicopter being prepared for its mission. With technology developed by Qualcomm Technologies Inc., this autonomous vehicle highlights the importance of integrated communication and computing systems–both on Earth and beyond (see page 7 for more information on the cover). We thank our authors and Qualcomm Technologies Inc. for their contributions to this issue.

WINNER 2021 APEX® AWARDS FOR PUBLICATION EXCELLENCE

IEEE-HKN was honored twice in the 2021 Annual APEX Awards for Publication Excellence. *THE BRIDGE* magazine received APEX recognition in the Writing Series Category for the articles by the National Renewable Energy Laboratory (NREL) in the October 2020 issue. This award is the eighth consecutive win by the magazine in various categories. Articles such as these expose our readers to timely technologies and to exciting career opportunities. IEEE-HKN received its first-ever Grand Award for the new Identity Guidelines, which were developed by the IEEE-HKN Public Relations and Communications Committee. These Chapter resources provide quality templates for graphic applications and guidance on the society's logo, colors, etc. Congratulations to our volunteers and staff for creating such valuable products!

The magazine is open access. An archive of the recent issues is on our website. The current issue of the magazine is also available on the IEEE App.

THE BRIDGE is on the IEEE App

IEEE-HKN Wins Top Award in Publishing Excellence Competition

The honor society receives its first-ever APEX Grand Award and the Honor society's magazine brings home its 8th consecutive Award of Excellence.

IEEE-Eta Kappa Nu (IEEE-HKN), the honor society of IEEE, is thrilled to announce it has won two awards in the 33rd Annual APEX Awards for Publication Excellence.

IEEE-HKN garnered its first-ever Grand Award in the competition for the "IEEE-Eta Kappa Nu (IEEE-HKN) Identity Guidelines" and its eighth consecutive Award of Excellence for its magazine, *THE BRIDGE*.

The APEX Awards are based on excellence in graphic design, editorial content, and the ability to achieve overall communications excellence. The annual competition is open to corporate and nonprofit publishers, editors, writers, and designers who create print, web, electronic, and social media.

A total of 1,172 entries were received.

The organization noted: "Overall, this year's entries displayed an exceptional level of quality. The APEX judges saw only the most promising publications that professional communicators could enter. From them, they had the truly difficult task of selecting the award-winning entries."

The "IEEE-HKN Identity Guidelines" are increasing recognition of the organization's brand and has given the society's 268 university-based Chapters a ready-to-use resource for developing promotional pieces, social media templates, letterhead, business cards, and the like. Some 14 templates were developed in addition to a step-by-step guide on how and where to use them. The rules around the use of the society's logo, colors and other brand elements also were explained.

The templates are widely used as evidenced by the social media posts Chapters have created and in the reports they submit to headquarters, said Nancy Ostin, IEEE-HKN Director.

The project was conceived and completed by Katelyn Brinker, Co-Chair of the IEEE-HKN Public Relations and Communications Committee; Stacey Bersani, IEEE-HKN Program Manager, and Caitlin Leshiner, owner and creative director of Tumbleweeds Creative Studio in partnership with the IEEE Experience Design team.

"This comprehensive resource has been embraced by our Chapters, and the organization as a whole and has helped all of these many parts come together under a single banner and have a shared reference point," said Ronald Jensen, 2021 IEEE-HKN President. "I thank and applaud Katelyn, Stacey and Caitlin for their dedication to producing a terrific product."

IEEE-HKN's electronic magazine, *THE BRIDGE*, received its eighth consecutive Award of Excellence in the competition. The latest winning entry was for the writing of a series of articles that appeared in the October 2020 issue, entitled "*THE BRIDGE*: The Future of Renewable Energy."

The issue was guest edited by Dr. Roderick Jackson, Laboratory Program Manager for Buildings Research at The National Renewable Energy Laboratory (NREL). Ostin served as Managing Editor and Bersani served as Assistant Managing Editor.

The series discussed the future of energy generation, transmission and consumption and the paradigm shift needed to achieve clean, reliable, resilient, and affordable energy. Jackson enlisted leading researchers at NREL to write the articles.

"This article series is a valued outreach from innovators in engineering to the next generation of engineers. Our student readers are exposed to key perspectives on timely technologies and to exciting career opportunities," said Dr. Steve E. Watkins and Dr. Sahra Sedigh Sarvestani, Co-Editors-in-Chief for *THE BRIDGE*, who lead the volunteer editorial board. "Excellence in professional communications through the magazine reflects the high ideals and impact of HKN."

Development of CDMA by Irwin M. Jacobs and Andrew J. Viterbi

By Steve E. Watkins, Gamma Theta Chapter

Dr. Irwin M. Jacobs and Dr. Andrew J. Viterbi were elected Eminent Members of Eta Kappa Nu in 2003 and 2006, respectively. Dr. Jacobs is former chairman of Qualcomm and holds a Ph.D. from the Massachusetts Institute of Technology. Dr. Viterbi is Presidential Chair Professor at the University of Southern California and holds a Ph.D. from the University of Southern California. Both are National Academy of Engineering members, IEEE Fellows, and IEEE Medal of Honor recipients. They co-founded Qualcomm Inc. with others in 1985. A prominent success of this company was the development of Code Division Multiple Access (CDMA) technologies for wireless communications. IEEE recognized the importance of this contribution through its Milestone program, see the Milestone description here.

CDMA is a spread-spectrum communication approach in which users share a single channel. Each transmitted digital signal is given a code that allows it to be reconstructed with the competing signals being received as background noise. Qualcomm demonstrated that CDMA could be viable technology for commercial wireless communication in 1989. Through such demonstrations and later innovations, Qualcomm pioneered the transition away from Time Division Multiple Access (TDMA) technology. CDMA became the technical basis for the second-generation IS-95 cellular standard and for third-generation cellular communication networks.

Figure 1. Dedication of IEEE Milestone Development of CDMA for Cellular Communications (1989) with Dr. Irwin M. Jacobs and Dr. Andrew Viterbi, co-founders of Qualcomm Inc. and Eminent Members of Eta Kappa Nu.

The milestone plaque is located outside the main entrance of the Qualcomm headquarters in San Diego, CA. It reads "Development of CDMA for Cellular Communications, 1989. On 7 November 1989, Qualcomm publicly demonstrated a digital cellular radio system based on Code Division Multiple Access (CDMA) spread spectrum technology, which increased capacity, improved service quality, and extended battery life. This formed the basis for IS-95 second-generation standards and third-generation broadband standards that were applied to cellular mobile devices worldwide." Figure 1 shows Drs. Jacobs and Viterbi at the dedication on 7 November 2017.

What are IEEE Milestones?

"The IEEE Milestones program honors significant technical achievements in all areas associated with IEEE. It is a program of the IEEE History Committee, administered through the IEEE History Center. Milestones recognize the technological innovation and excellence for the benefit of humanity found in unique products, services, seminal papers and patents. Milestones are proposed by any IEEE member, and are sponsored by an IEEE Organizational Unit (OU)—such as an IEEE section, society, chapter or student branch."

Resourced from https://ethw.org/Milestones:IEEE_Milestones_Program

Mu Nu's Podcast Series Features Industry Leaders and Professors Focused on Innovation for Greater Impact

By Gilberto Manunza, Corresponding Secretary of the Mu Nu Chapter of IEEE-HKN, Matteo Sartoni, Vice President Elect of the Mu Nu Chapter of IEEE-HKN, Riccardo Zaccone, Graduate Student Member of the Mu Nu Chapter of IEEE-HKN, Veronica Montanaro, Web Correspondent Elect of the Mu Nu Chapter of IEEE-HKN

Research Radio season two was born from the idea of giving a more applied perspective into innovative technologies. During this event series we interviewed companies having a great impact on our society and professors working on cutting-edge technologies.

The format of each episode consisted of an online interview livestreamed on YouTube plus a Q&A session with the participants. To keep the audience's attention, we gave a reward to the most active participants by sharing a survey on the covered topics.

Research Radio—Innovation #1: Eugenio Sapora, Too Good To Go

Our guest was Eugenio Sapora, the Italian country manager of Too Good To Go, a company whose mission is to inspire and empower everyone to take action against food waste. To do so, their app permits customers to order leftover, but still good, food from restaurants, at a discounted price.

Eugenio touched upon the social and economic aspects of this mission and the technical details around their IT infrastructure. The survey's winners received some free orders from the company's app.

Research Radio—Innovation #2: Alessio Tommasi, Gemmate Technologies

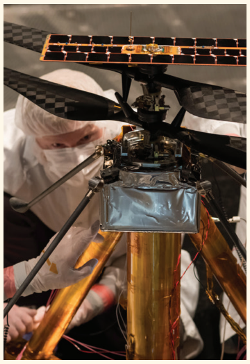
For this episode we had the pleasure to host Alessio Tommasi, technical manager of Gemmate Technologies, a company involved in additive manufacturing. This technology was analyzed from multiple aspects, ranging from the economic benefits to the technological aspects and touching upon topics like fast prototyping and connections with AI. For this event, the survey's winners received some Amazon coupons offered by the company.

Mu Nu Chapter of IEEE-Eta Kappa Nu

continued on page 8

About this Month's *THE BRIDGE* Cover

Shown is NASA's Ingenuity Mars Helicopter, supported by the Qualcomm Flight™ Platform designed to meet the unique challenges of flight operation on Mars. Qualcomm Technologies, which includes Qualcomm Government Technologies and Qualcomm CDMA Technologies, worked closely with JPL to develop technologies and solutions that powered the Mars helicopter for its inaugural flight. The Qualcomm Flight Platform was developed with autonomous flight in mind, featuring 4K ultra-HD video, heterogeneous mobile computing, navigation via visual inertial odometry, and flight assistance – all in an extremely small and durable package. These critical features came to mind when JPL considered the constraints of remotely operating a helicopter on Mars, and the complex algorithms it would need to compute. On April 19, 2021, Ingenuity successfully completed the first powered controlled flight by an aircraft on a planet besides Earth, taking off vertically, hovering and landing. Since then, it has made a total of 9 successful flights Cover image Courtesy NASA/JPL-Caltech. Qualcomm Flight is a product of Qualcomm Technologies, Inc. and/or its subsidiaries.



Mu Nu's Podcast Series Features Industry Leaders and Professors Focused on Innovation for Greater Impact

continued from page 7

Research Radio—Innovation #3: Antonio Valitutti, HYPE

HYPE, an Italian banking startup, offers a very interesting card, since the payment process is simplified, and it works with various currencies with small commissions. With Antonio we talked about the banking sector and the engineering aspects behind its related infrastructure. For this event, the survey's winners received some Hype Gadgets.

Research Radio—Innovation #4: Applications, 5G networks and risks on the public health related to 5G

5G is a hotly debated technology. Beyond the technological challenge there is the promise of better services enabling technologies not possible before. But, there are public health concerns. We spoke several professors for this episode:

- Claudio Casetti, professor at Politecnico di Torino, explained what 5G is and the technical differences between it and 4G.
- Luca Chiaraviglio, professor at Tor Vergata University of Rome, analyzed the health aspects related to 5G, with a focus on how recent studies proved that 5G is safe for the public.
- Paolo Giaccone, professor at Politecnico di Torino, demonstrated, with his Ph.D. student Riccardo Rusca, some 5G devices installed throughout the university for monitoring the flow of people, and he talked about some possible applications related to 5G.

This second season of Research Radio was a success for the Chapter, with the videos reaching almost 1,300 views on YouTube.

"We truly believe we have reached our goal of giving to our members and to the other students at our university the possibility to interact with important players in different fields," the authors concluded.

Congratulations, Key Chapter Winners!

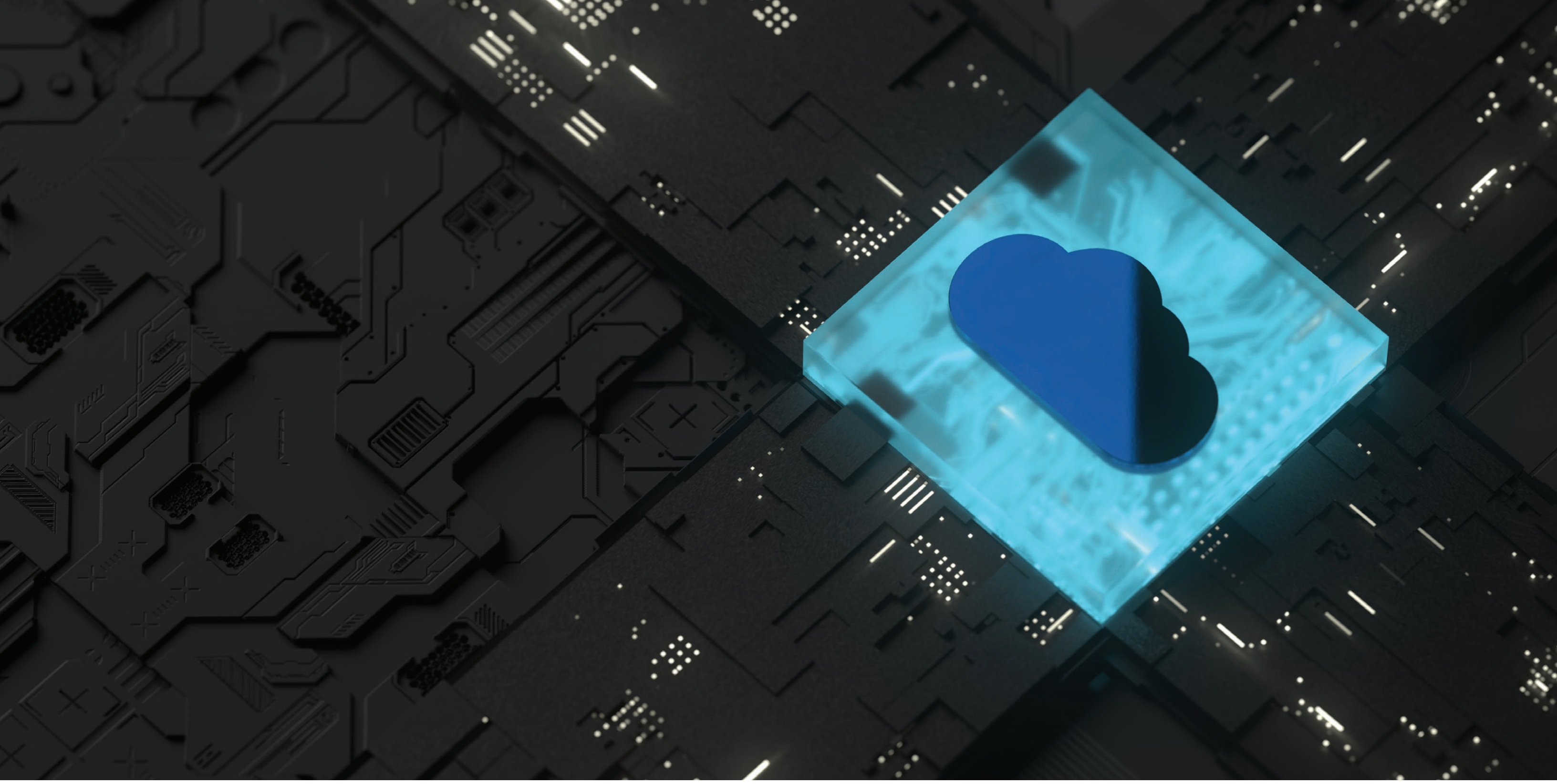
IEEE-HKN is excited to announce that 63 Chapters have achieved Key Chapter status for the 2020-2021 academic year. The Key Chapter recognition celebrates chapters that participate in activities identified as the best practices of successful chapters. Every Chapter has the potential to earn the Key Chapter recognition.

Congratulations to the members, officers, Faculty Advisors and Department Heads of the following Chapters:

Alpha	Univ. of Illinois at Urbana-Champaign
Beta	Purdue University
Beta Delta	University of Pittsburgh
Beta Epsilon	University of Michigan
Beta Eta	North Carolina State University
Beta Lambda	Virginia Tech
Beta Mu	Georgia Institute of Technology
Beta Nu	Rensselaer Polytechnic Inst.
Beta Rho	West Virginia University
Beta Xi	University of Oklahoma
Delta	Illinois Institute of Technology
Delta Omega	University of Hawaii at Manoa
Delta Xi	Air Force Institute of Technology
Epsilon	Pennsylvania State University
Epsilon Beta	Arizona State University
Epsilon Delta	Tufts University
Epsilon Epsilon	University of Houston
Epsilon Eta	Rose-Hulman Institute of Tech.
Epsilon Mu	University of Texas at Arlington
Epsilon Omicron	University of Delaware
Epsilon Phi	California Polytechnic State University
Epsilon Sigma	University of Florida
Epsilon Xi	Wichita State University
Gamma Alpha	Manhattan College
Gamma Beta	Northeastern University
Gamma Chi	New Mexico State University
Gamma Mu	Texas A & M University
Gamma Psi	Lafayette College

Gamma Theta Food Bank Volunteering

Gamma Tau	North Dakota State University
Gamma Theta	Missouri University of Science and Technology
Iota Delta	Stevens Institute of Technology
Iota Gamma	University of California, Los Angeles
Iota Lambda	University of Illinois, Chicago
Kappa Alpha	Northern Illinois University
Kappa Epsilon	State University of New York—Binghamton
Kappa Psi	University of California, San Diego
Kappa Sigma	Boston University
Kappa Tau	Baylor University
Kappa Upsilon	University of Texas, San Antonio
Lambda	University of Pennsylvania
Lambda Beta	California State University, Northridge
Lambda Omega	National University of Singapore
Lambda Omicron	Miami University
Lambda Tau	University of Puerto Rico at Mayaguez
Lambda Zeta	University of North Texas
Mu	University of California, Berkeley
Mu Alpha	UCSI University—Kuala Lumpur
Mu Beta	Arab Academy For Science & Tech—Alexandria
Mu Kappa	University of Queensland
Mu Nu	Politecnico Di Torino
Mu Omega	Florida Polytechnic University
Mu Rho	Valparaiso University
Mu Sigma	National Chiao Tung University
Mu Zeta	Western Washington University
Nu	Iowa State University
Nu Alpha	Univ Nacional De Educacion A Distancia
Omicron	University of Minnesota
Tau	University of Cincinnati
Theta Lambda	University of South Alabama
Zeta Chi	University of Central Florida
Zeta Eta	Brigham Young University
Zeta Iota	Clemson University
Zeta Omega	University of California, Irvine



Quality-of-Service Architecture for Cloud Computing Networking

By Ken R. Owens, Jr. Senior Member, IEEE, VP Cloud Security Engineering, Fiserv, St. Louis, Gamma Theta 1999 and Steve E. Watkins, Senior Member, IEEE, Department of Electrical and Computer Engineering, Missouri University of Science and Technology, Gamma Theta 1982

Abstract

Quality-of-service (QoS) performance is an important consideration for real-time and high-priority traffic on internet protocol (IP) networks. Service differentiation can provide a more efficient and customer-oriented internet. The "best-effort" internet models in use today cannot provide guarantees or service differentiation for end-to-end individual and aggregate data flows. Hardware-based models and software-based models do not completely address the total service-enabled solution. We propose a hybrid architecture that combines software and hardware features to handle network traffic with diverse QoS requirements. Since cloud providers leverage IP networks today, the model is based on a systems engineering approach that uses cloud computing technologies. The work describes the conceptual model and the reference model for the hybrid QoS system. Service levels can be defined in terms of absolute or relative guarantees on loss, delay, bandwidth, and burst size. End-to-end characteristics of individual flows are maintained within the aggregate flows of cloud network traffic.

I. Introduction

The modern uses of internet networks include real-time and high-priority traffic that are poorly served by "best effort" quality guarantees. The need for finer granularity in service quality is widely recognized [1,2]. Reliability guarantees and service differentiation are clearly required for applications with mission-critical business data. A viable option for end-to-end differentiation of service is taking advantage of quality-of-service (QoS) features within the cloud providers network. A path-oriented technology can be used to support quality guarantees in existing networks [3]. In conventional "legacy" forwarding, a router will forward a data packet based on the longest prefix match for the packet's destination internet protocol address. As the packet transverses the network, each hop in turn forwards the packet by reexamining its destination address; the encoding of the path introduces significant overhead. In contrast to legacy internet protocol (IP) networks, a packet is assigned a label upon entry into a QoS cloud-enabled network. At subsequent hops,the label is used as an index into the table that specifies the next hop and a new label. The old label is swapped with the new label and the packet is forwarded to its next hop. Consequently, the identity of the explicit path need not be carried with the packet and dynamic routing algorithms may be exploited.

Common architectural models approach QoS from just a hardware or a software perspective [4,5]. Telecommunications modeling considers the design rules for the transport layer network and the control layer network. Data communications modeling uses software to control hosts and routers in the protocol layer. Consequently, the layer network architecture and the protocol layer architecture address different aspects of the QoS needs, but they are insufficient to provide the total solution individually.

This work describes a systems engineering approach for providing end-to-end service differentiation for an internet protocol (IP) network. A model is proposed that uses cloud computing networks and elements to facilitate implementation within existing infrastructure. This approach leads to a hybrid model that integrates hardware and software features to provide quality of service (QoS). The hybrid system model architecture is designed to meet QoS requirements of individual data flows while operating on flow aggregates. This model defines service levels in terms of absolute or relative guarantees on loss, delay, bandwidth, and burst size. The needed data, control, and management paths of networks and network elements are discussed, as well as the associated traffic engineering protocols. The conceptual model and the reference model for the hybrid QoS system can be implemented easily with existing networks.

II. BACKGROUND

IP networks are complex and multi-faceted. They incorporate concepts that are rooted in both telecommunication and data communication technologies. With the market interest in transforming IP networks from "best effort" to QoS aware, network models from both areas are being explored as vehicles for the needed network evolution. We contend that neither model, in themselves, adequately address the need for protocol layer separation and end-to-end QoS assurances. A hybrid model can combine aspects of the telecommunication model of layer networks and the data communication model of protocol layering.

The telecommunication model of layer networks describes the architecture of controlling and transmitting data and the associated communication design rules. The data communication model of protocol layering is concerned primarily with the structure of software found in hosts and routers that carry network data. These models deal with complementary concepts of network modeling and layering that are inherent in protocol design and analysis.

A. Layer Network Architecture

The layer network architecture consists of two-layer networks partitioned into one or more regions called sublayers. Currently the International Telecommunications Union (ITU) has defined the transport and control layer networks [6]. The transport layer network consists of the characteristic information transfer defined as the data plane flow. The control layer network consists of the control of the characteristic information transfer.

The transport layer network is comprised of the generic architectural elements and the data path that they form. The functionality provided by the layer network architecture consists primarily of termination, connection, and adaptation functions. The termination function provides the functionality of terminating and processing of the characteristic information in a layer.

The connection function provides protocol layer interconnection. The modification between the termination function and the connection layer function is defined by the adaptation function. The adaptation function provides adaptation between the lower-layer functions and the upper-layer functions.

The control layer network is comprised of the generic architectural aspects of element control. Element control is responsible for control of the transport layer configuration and maintenance.

B. Protocol Layer Architecture

Data communications also has a layering approach called protocol layering. Data communications advances have been targeted at the protocol layers, which are mostly software, until recently. The need for multi-protocol processing and processing at wire speed has been causing some concerns in the data communications community. Multi-protocol means that several different protocols, at various layers of the protocol stack, must be processed simultaneously. Until the last few years, almost all protocol processing was performed in software. Recently, the increased capacity (10 Gbps) of data networks has caused a new paradigm in data communications. This shift is to perform protocol processing in hardware at wire speed.

While layer network architecture provides a hardware foundation for networking, the protocol layering is the basis for internet operation and will remain so for some time. The design requirement for protocol development is to specify protocols that enables communications without having to understand what aspects of the network are processing below this protocol and which aspects are above the protocol. In other words, protocol independence is a requirement to communicate in a multi-protocol environment. This protocol independence is the crux of the protocol layering perspective as described in the literature [7].

This protocol processing is quite complex. Each layer that the message transverses has its own set of attributes and requirements. Some of the attributes for each layer are verifying the correctness of the message, classifying the message and making a forwarding decision based on the rules for this message.

III. QUALITY OF SERVICE WITH CLOUD PROVIDERS

One approach for QoS in cloud services is to identify controllable and uncontrollable factors. A system designer for a hybrid system QoS architecture must addresses the controllable factors of QoS [8]. The controllable factors include design decisions and implementation trade-offs, for example buffer size, scheduling algorithm, and metering algorithm. The uncontrollable factors include physical delays, for example line speed, propagation, and contention delay.

A. Objective and Scope

The objective of QoS is the differentiation among different services of user traffic. QoS can be an absolute guarantee or a relative guarantee. The guarantees are on traffic characteristics such as loss, delay, bandwidth, and burst size. For example, burst size could have an absolute guarantee of 96 kbytes or a relative guarantee that normally the burst size would not exceed 96 kbytes. The service model must translate user needs into controllable technical limits.

This problem space would be simpler if all user traffic services were individual flows that could be easily identified. However, the nature of the internet, and particularly IP, is to aggregate multiple individual flows at the entrance to the network and treat the flows as an aggregate in the edge and core of the network. Aggregation of individual flows greatly simplifies the processing required in devices. However, the trade-off of this simplification is in the quality and reliability guarantees. The hybrid system QoS architecture must aim to honor QoS requirements of individual flows while operating on flow aggregates.

In understanding the scope of this problem, traffic engineering principles should be applied to define the solution formally. Cloud network traffic engineering considerations include defining attributes that associate with aggregate flows in order to specify and constrain behavioral characteristics. The traffic attributes can be associated with resources that constrain the placement of label switched paths (LSP) and the flows associated with each LSP. Constraining the type of flows that can be aggregated together brings about defining formal arrangements for when aggregation and de-aggregation occurs. Therefore, the scope of the QoS architecture encompasses traffic engineering of cloud network flows with diverse QoS requirements. The associated tasks are:

- To define a formal architecture for which traffic engineering policies are attached and
- To define a set of policies associated with the formal model that can be disseminated to each switch or router [9].

Traffic engineering resources must be defined with regard to the reference architecture to meet the end-to-end serviced differentiation.

B. Service Definition

The current internet supports only the "best effort" service class model. The desire is to change this model and have the internet support other services in addition to "best effort." The motivation is to create pricing models that enable the service provider to create more services that attract and keep customers, as well as to create a price structure for finer granularity of service quality. This paradigm shift toward a new pricing model has been called a service-enabled model. The hybrid system QoS architecture addresses this need. User expectations are key to any QoS development. User expectations are defined by the perceived quality and service that the users expect to receive as a value-paying customer, i.e. one that is paying a particular rate for a guaranteed service level. While there are no standardized service models as present, the general approach for service-enabled model development is based on three categories beyond best effort.

- **Premium service attributes:** Highest level of quality with the strictest assurances in a contract.
- **Guaranteed service attributes:** Intermediate level of quality with some assurances in a contract.
- **Better-than-best effort service attributes:** Lower level of quality with the minimal assurances in a contract.
- **Best effort service attributes:** Highest level of quality with the no assurances.

This structure allows for pricing in four tiers. Given these general rules for enabled service creation, the service providers can build their enabled services to conform to the general rules. One proposed service enabled model that supports these rules is called the Olympic Service Model with Gold, Silver, and Bronze Services [10]. Gold, Silver, and Bronze correspond to Premium, Guaranteed, and Better-than-Best Effort services.

C. Conceptual Model for Hybrid System

The initial stage in developing the hybrid system QoS network model is to define the model conceptually. Network architectures generically describe the data, control, and management paths of networks and network element. The functional decomposition of the hybrid system network architecture conceptual model is displayed in *Figure 1*.

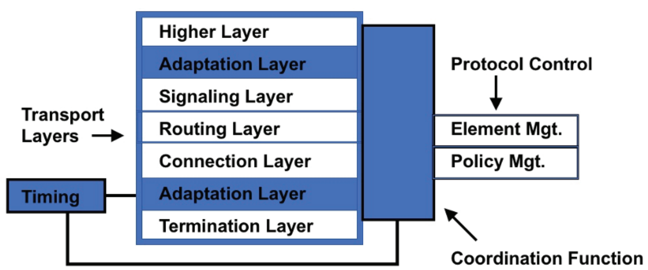


Figure 1: Functional Decomposition of Hybrid System Network Architecture

The functional decomposition displays the transport layer network components to the left of the coordination function and the control layer network components to the right of the coordination function. The transport layer network components are layered based on the protocol functionality. The coordination function represents the in-band and out-of-band communication between the management functions and the data and control plane functions. The blocks for the timing and interworking functions are provided to complete the network architecture.

In addition to the transport, control, and protocol layering of the architecture components and interfaces, the QoS reference model must specify the following aspects.

- Traffic Engineering implementation of flows with diverse QoS requirements.
- Definition of a formal architecture to which traffic engineering policies are attached (such policies include priority, QoS, preemption, authorization, and logging of events).
- Definition of policies used by the Network Manager to disseminate to a switch or a router to meet individual flow guarantees.

The resulting hybrid concept will have components in the data plane, control plane, and management plane. The dataplane includes physical connectivity based on SONET, SDH, Ethernet, etc., label switching service through MPLS, and transport layer routing and adaptation in IP. The control plane includes selected protocols that are constrained by the QoS rules. The management plane provides policy schemas and decisions and element support.

D. Reference Model for Hybrid System

A reference model describes entity partitioning, functionality, and their components. Additionally, a reference model describes the communication between entities. The hybrid system QoS reference model is displayed in *Figure 2*.

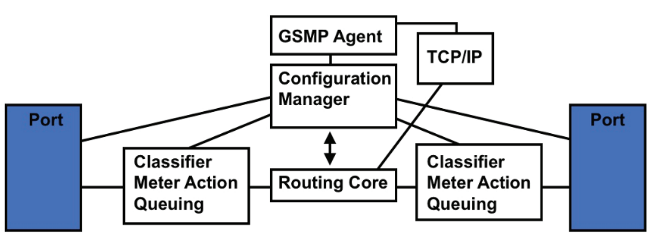


Figure 2: Hybrid System QoS Reference Model

The reference model is partitioned into the element entities that are connected by the data path. The element entity represents the transport layer or data path layer. Each element has an element controller entity that is connected to the element and the other element controllers by the control path. Each element controller entity represents the control layer or control path. Together the elements and the element controllers provide all the data and control functionality of the network. Hence, the management functionality of the network is provided by an element management system, policy management server, and QoS management server. The QoS server handles data path processing based on traffic engineering, e.g., classifying, metering, and queuing.

This reference model basic functionality and should not be taken as a logical architecture. Every element does not necessarily have a dedicated element controller. Additionally, the element management system, policy server, and TE/QoS server could be one logical component.

E. Element Reference Architecture

In the QoS reference architecture, the element entity is functionally responsible for all the data path processing. The element entity is partitioned into the components shown in *Figure 3*. The element reference architecture consists of datapath processing and control functionality. The physical ports for ingress and egress provide connectivity to the element entity. A routing core provides connectivity between the ingress and egress ports. The network processors provide functionalities of classification, metering, queuing, and protocol actions. The ports, routing core components, and network processors are all configured by the configuration manager. A hardware interface between the element and the element controller is provided by the General Switch Management Protocol (GSMP) Agent and TCP/IP components.

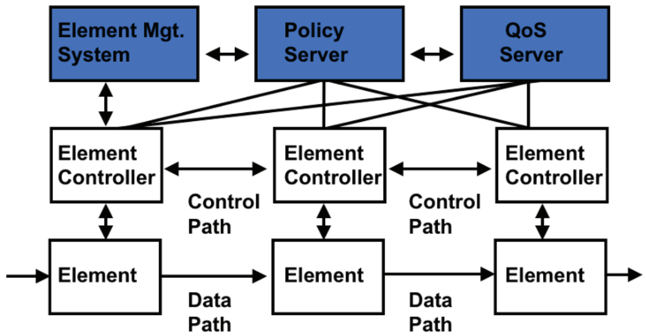


Figure 3: Element Reference Architecture

IV. TRAFFIC ENGINEERING

Traffic engineering resources set the protocols for directing and prioritizing the flow of data. A traffic conditioning specification contains the necessary information to conduct conformance testing of the data packets. It defines a traffic profile for allocating resources and parameter values for operating the meter. Finally, a service layer agreement between the network and the user guarantees a specific compliance for the user's data.

A. Traffic Parameters

Traffic parameters are selected that fulfill the following requirements:

- The parameters must be understandable by the end system and must be subject to conformance testing.
- They must relate to network performance, i.e. part of resource allocation schemes.
- They must be enforceable by the meter entity.

Service layer agreements will be defined in terms of such parameters. Useful parameters include peak data rate, committed data rate, peak burst size, committed burst size, and excess burst size.

B. Metering

Service layer agreements are implemented by the QoS server and its metering algorithm. Data flow aggregates will be manipulated to fulfill guarantees on individual data packets and associated traffic profiles. In particular, a meter entity measures the parameters for which passing data packets, compares the parameters to selected thresholds, and selects among the possible actions. The desired traffic profile will be maintained by queuing actions on individual data packets of marking, dropping, or passing. For instance, traffic is subject to a conformance test. The algorithm will forward the data packet without change, mark the packet to display some level of non-conformance, or drop the packet based on non-conformance.

V. CONCLUSIONS

Cloud providers support services and network functions with dynamic routing algorithms that may be exploited for QoS guarantees. A hybrid system model is proposed that meets QoS requirements for individual data flows while operating on flow aggregates. This model integrates hardware and software features to handle absolute or relative service guarantees on loss, delay, bandwidth, and burst size. The model architecture was developed to address the design of reference models, functions, and algorithms. The functionality and flexibility of cloud computing technologies is used to automate the needed traffic engineering protocols. This architecture may be implemented easily in existing cloud provider networks and network elements.

The hybrid system is designed to enhanced granularity of services with service levels such as premium, guaranteed, better-than-best effort, and best effort. The needed processing will classify, meter, and queue data packets to satisfy service layer agreements. This service improvement can be shown to handle a complex traffic environment including voice, video, database, http, and e-mail applications.

ACKNOWLEDGEMENTS

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Analyzing Service Mesh Performance

By Lee Calcote, Layer5; Mrittika Ganguli, Intel; Sunku Ranganath, Intel; Otto Van Der Schaaf, Red Hat

I. Introduction

As a forthcoming, ubiquitous layer of cloud native infrastructure, service meshes offer deep and uniform control and visibility into the topology and state of ephemeral microservices. Managing the myriad configurations of cloud native infrastructure is greatly facilitated by a service mesh, but succinctly summarizing and characterizing the performance of your service mesh in context of your unique workloads and your infrastructure of choice is a challenge unto its own [1-3].

We explore how to model your service mesh topology and optimize for your ideal configuration in context of how much you value properties of resiliency, performance, throughput, latency, and so on before you deploy to production. Readers will understand how distributed performance analysis offers unique insights on the behavior of microservices and their efficiency of operation, see examples of how common types of workloads perform under specific service mesh functions, and be empowered with analytical tooling that can be used to make optimized configurations.

We provide core, memory and I/O combinations based on workload needs with insights into workload analysis which can influence the efficiency of the service mesh and overall performance of the cluster.

II. Characterizing the Complexity of Combinatorial Analysis

Consider that the more value you try to derive from your service mesh, the more work that you will ask it to do. Said another way, an analysis of the architecture of a service mesh - with its distributed proxies - and the functionality it offers will lead to the question, "What overhead is running my service mesh incurring?" This is not an easy question to answer as the permutations of configuration between your infrastructure, service mesh, and applications are innumerable and any change to one of them affects their collective performance.

How would you describe the performance of your service mesh and that of your clusters and their workloads? Are you imagining a wall of line charts with metrics capturing golden signals? The act of articulating the performance of your service mesh requires you to characterize the state of your systems and the overhead incurred by your infrastructure and to consider what this means to your users.

Moreover, when performance is characterized, the analysis is subjective to the specific workload, infrastructure, and instruments used for measurement. Given the variety of this measurement challenge, the providers of most service meshes and their data plane proxies (if there is a third-party component) do not have the tooling necessary for or refuse to publish performance data. Such tests can be arduous to create and sustain a capable harness, a point-in-time consideration (none of the elements under measurement are static), and misinterpreted. These challenges are considered in the next sections.

III. Service Mesh Perfomance Considerations

As the software-defined networking layer of microservices, service mesh encompasses multiple aspects of critical functions for applications, such as circuit breaking, health checks, and packet operations. Analyzing the permutations of these configurations is an impossible task without a suitable test harness. A service mesh management plane can be such a tool. As the multi-mesh manager, Meshery is capable of provisioning ten different service meshes, workloads atop the meshes, generating load using Nighthawk and analyzing that load. No other tool capable of performing these tasks end-to-end exists. Meshery is a Cloud Native Computing Foundation project originally created by Layer5 [4]. Nighthawk is a Layer 7 (HTTP/HTTPS/HTTP2) performance characterization tool created by Envoy community [5].

A. How Are You Measuring?

Consider the simple set of steps to execute performance tests in a simple Kubernetes-based cluster:

1. Setup your cluster, service mesh, and application under test.
2. Pick a benchmarking tool that can measure Layer 4 or Layer 7 performance.
3. Configure your test setup for performance, doing so in context of other constraints that you might need to uphold (e.g. resiliency characteristics of your service deployment).
4. Choose the protocol of interest such as HTTP, HTTPS, HTTP1/2, gRPC, or NATS.
5. Identify key performance indicators (KPIs) of interest - Transactions per second (TPS) or percentile latencies, etc.
6. Decide on the test duration such as 60 seconds, 5 minutes, or 1 hour.
7. Choose the number of requests per second (RPS).
8. Execute the test.
9. Mark down requests per second, latencies, throughput, and any other output provided by benchmarking tools.

Note that Kubernetes is an open-source platform for managing cloud-native applications.

B. What are you measuring?

Performance of a service mesh can be described across multiple dimensions covering some or all of these core functionalities of a service mesh. So, which dimensions are the linchpins of performance? Which metrics are key indicators of performance? Outside of the different types of performance tests, performance management concerns include the need for performance and overhead data under a permutation of different workloads (applications) and different types and sizes of infrastructure resources. Hence, it is crucial to understand what is being measured in a service-mesh-based deployment. Certain critical considerations are missing from the simple methodology previously described. *Figure 1* gives examples using the Service Mesh Performance (SMP) standard which is a specification developed by within the cloud computing community [6]. Ultimately, the goal of any performance tests is to ensure repeatable measurements and obtain consistent results across multiple test runs. A list of test considerations includes the following.

TRAFFIC CONSIDERATIONS

- **East-West traffic**
  - between two pods within the same or two different Virtual Machines (VM).
  - between two pods within the same or two different bare metal nodes.
  - combination of above with choice of user-space or kernel-space networking stack on the host node.
- **North-South traffic**
  - Throughput and latency of traffic flowing in and out of a single VM or across a single bare metal node.

DEPLOYMENT CONSIDERATIONS

- Number of hops between traffic source and traffic destination with load balancers, API gateways, ingress controllers, security components such as firewall, deep packet inspectors, and so on.
- Operating system settings.
- Hardware settings such as BIOS options, power management features, NUMA awareness, platform resource management, hardware accelerators, and so on.

LOAD GENERATORS TYPES

- hardware or software based, L2-3, L4-7, open or closed loop.

SERVICE MESH TYPES (The Service Mesh Landscape has over twenty meshes listed [7]. Each share a common architecture, however, their implementation differs and consequently, so does their performance.)

- Control plane - often a point of contention the larger the service mesh deployment is.
- Data plane - not only proxies, but filters loaded in those proxies.

SERVICE MESH CONFIGURATION AND NUMBER OF SERVICES ON THE MESH

- Telemetry
  - Including the three pillars of observability are traces, logs, and metrics.
  - The number of, cardinality of, sampling rate, ingest rate… all bear weight (and bear load on the system).
- Policy
  - Authentication, Authorization - frequency of checks, cache hits versus cache misses.
- Security
  - Encryption - overhead of handshaking and mutually authenticated TLS.

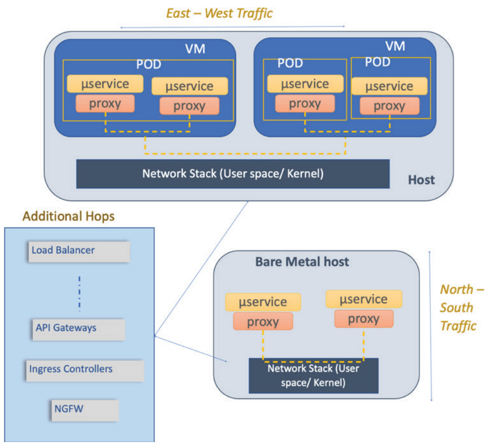

Figure 1: Performance considerations for testing a service mesh

IV. SERVICE MESH PERFORMANCE AS A SPECIFICATION

The need for cross-project, apple-to-apple comparisons are also desired in order to facilitate a comparison of behavioral differences between service meshes and which one might be best-suited for specific workloads. Individual service mesh projects shy from publishing test results of other, competing service mesh projects. The need for an independent, unbiased, credible, standard measurement is one of the catalysts for the creation of Service Mesh Performance (SMP) [6]. The SMP standard is a specification and a means to disseminate insights and research results. The authors are working toward the definition of MeshMark, a universal performance index to gauge your mesh's efficiency against deployments in other organizations' environments.

Many performance benchmarks are limited to single instance load generation (single pod load generator). This limits the amount of traffic that can be generated to the output of the single machine that the benchmark tool runs on in or out of a cluster. Overcoming this limitation would allow for more flexible and robust testing. Distributed load testing in parallel poses a challenge when merging results without losing the precision we need to gain insight into the high tail percentiles. Distributed load testing offers insight into system behaviors that arguably more accurately represent real-world behaviors of services under load as that load comes from any number of sources.

The specification itself provides a standard format for describing and capturing:

- performance test configuration,
- service mesh configuration,
- environment configuration,
- workload configuration,
- performance test results,
- distributed performance modeling,
- key performance indicators (KPIs), and
- test tool requirements.

Value from a service mesh is best derived when it is tuned to scale as per the deployment requirements. Given the complexity of deploying, testing and measuring performance aspects across multiple dimensions, the specification aims to provide a simple starting point for anyone looking to understand and derive service mesh performance. The SMP standard aims to articulate these complexities in a methodical and automated manner in order for anyone to plan the performance scenarios of their deployment and execute relevant tests.

Figure 2 provides insight to the fact that the specification defines a common collection of statistical analysis to be calculated for every performance test.

```
message PerformanceTestResult {
  message Latency {
    double min = 1;
    double average = 2;
    double p50 = 3;
    double p90 = 4;
    double p99 = 5;
    double max = 6;
  }
```

Figure 2: Snippet of the Service Mesh Performance (SMP) specification describing how to capture statistical analysis test results.

V. DEFINING DEPLOYMENTS

Virtualized deployments involve deploying microservice orchestration and service mesh stack in virtual machines (VMs). Although bare metal usage has performance benefits, customers often use VMs to provide hardware-level isolation between various applications. This deployment involves two VMs across two nodes, with one acting as a Kubernetes master with the other a worker node. Customers deploy VMs on a single non-uniform memory access (NUMA) node to avoid cross traffic on an ultra path interconnect (UPI). Results in virtualized testing have shown that depending on pinning of QEMU threads to a set of isolated cores - either sequentially or clustering the threads together to all the cores - tail latencies are heavily impacted.

Microservice deployments could use a wide variety of deployment scenarios. The following list provides a sample set of how a service mesh performance could be analyzed either on a same node or in a multi-node cluster:

- Pod to pod communication.
- Pod to service communication.
- Ingress controller to pod and vice-versa.
- Load balancer to pod and vice-versa.
- Pod to Egress Gateway.
- Mutual transport layer security (TLS) termination across any of the above endpoints.
- Different security rules and policies.
- Communication protocol.

These considerations are illustrated in a typical workload deployment as shown in *Figure 3*.

An example of deployment with Kubernetes is an orchestrator using the open-source CNI [8] and deployed in VMs. The host infrastructure has the Open vSwitch data plane development kit (OVS-DPDK) for switching, which can be extended for VMs to leverage single-root I/O virtualization (SR-IOV). Fortio [9] can be the load generator. To highlight the performance impact of a service mesh and its set of data plane proxies, consider running Meshery in two different environments outside the Kubernetes cluster.

- First: load generator running as a process outside of Kubernetes cluster in master-vm.
- Second: load generator running as a bare metal process on master-host.

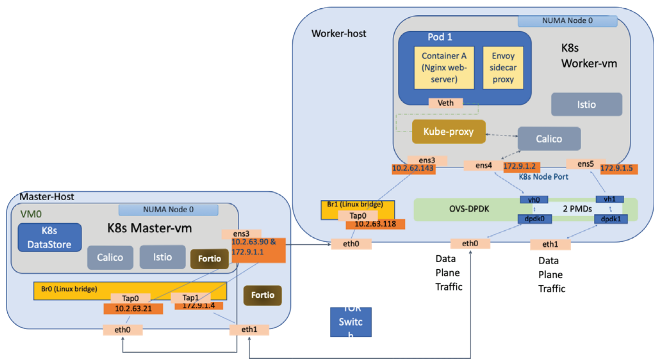

Figure 3: An enterprise workload deployment example

A. Automating Performance Measurements

Meshery is ideal tooling in that it provides lifecycle management of a large number of service meshes and sample applications which need to be provisioned, configured, and deprovisioned in the process of analyzing service mesh performance. Meshery is capable of generating load, baselining, and comparing performance results. The canonical implementation of this specification is implemented in Meshery, see *Figure 4*.

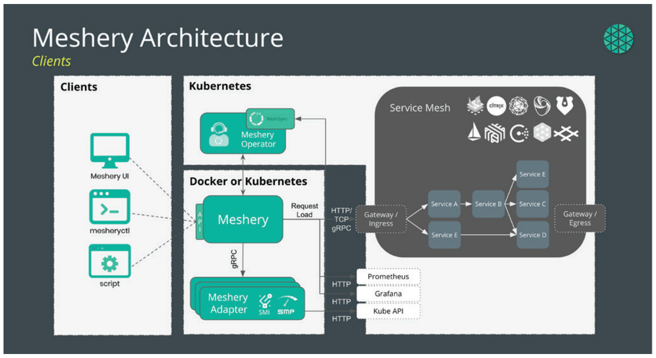

Figure 4: Meshery's load generators can be deployed in the same cluster under test or outside of the cluster test.

Acknowledging the living nature of user deployments, integration of automated performance testing into continuous integration systems helps users deploy new versions of their applications or new configurations of their infrastructure (including service mesh configuration) with the guarantee afforded through the act of dry-running the service mesh and application configuration before production deployment. The Meshery and Service Mesh Performance at GitHub Action (https://github.com/layer5io/meshery-smp-action) offers the ability to adaptively analyze application performance as a gate in your continuous delivery pipeline. In this way, the SMP specification facilitates a measurement index that can be referenced when rolling out new versions of a service with this advanced canary technique.

Through Meshery, techniques to mirror non-idempotent requests allow replay of user requests without fear of impacting the current version of your application. Through the use of intelligent network functions, embedded in WebAssembly (WASM) programs, to facilitate real user request reenactments, the most value can be extracted out of your pipeline. For example, repeatability of test scenarios can be investigated using performance profiles and cloud native orchestration and results can be baselined and compared.

B. Analyzing Performance Measurements

We have often seen inefficiencies in the ratio of resource usage versus resources applied. Since the mesh elements i.e. the ingress and sidecars share resources with one or more of the application containers, there may be more resources left to be utilized. **Tail latencies decrease with the increase in number of cores** for all 1, 10 and 100 clones but increase with the increase in the number of connections. Data for various connection counts, as shown, indicates that performance degradation with Istio (https://istio.io) shows up with input RPS more than 1000. In a top-down microarchitectural analysis (TMA) [10], the front proxy is pinned to a single core, the sidecar + flask app is pinned to another core, and the number of microservices are scaled up. It is observed that (cf. *Figure 2*):

- Frontend Bound% decreases with increase in number of microservices and Core Bound % increases.
- Memory Bound % increases with increase in the number of microservices.
- L1 and L3 Bound% decreases for both the service cores on which the front –proxy is running as well as the core where the sidecar+flask app is running with number of microservices.

In customer environments, the size of the cluster as well as the amount of incoming traffic will have an impact on the number of workloads and Envoy microservices. The underlying hardware and L4 networking on each node in the cluster will also impact the performance observed.

A call stack and cycles spent analysis of a deployment with 1-20 sidecars on a specific 40 core system with a 10G NIC shows bottlenecks spread between:

- Envoy: TheadLocalStorage-Hashset-Match,
- Linux kernel bottleneck spread between Libpthreadscheduling and Libevent,
- Envoy buffer slice management and TCP filter, if message sizes or file transfer sizes increase to 1M, and
- Crypto operations when TLS is enabled.

Our initial studies show that the optimal service mesh setup for the tolerable latencies and the best RPS may include:

- Exclusive threads allocated to Envoy processing,
- Reduced memory contention by allocating more memory bandwidth which can be controlled dynamically,
- Load balancing of worker threads among the among cores which may require less IO switching, and
- Optimized memory copies with signals incorporated in addition to events (libevent).

A number of accelerations and offloads to SMART NIC or other processing elements like IPUs and DPUs are becoming available. How does the service mesh efficiency and performance benefit from these deployment options needs to be defined and measured. Cycles and cores saved in the host cores versus offload cores, which may be of different architectures and/or performance range, needs to be quantified and benchmarked.

C. Being Precise in Performance Studies

When measuring sub-millisecond response times, the noise floor of the environment as well as the sensitivity of the tooling may become dominant factors in measurements. Noisy neighbors, scheduler fairness, garbage collection, connection-reuse patterns, and even specifics in the timing of requests being sent may change noise floors. Hence, similar measurements performed using different systems and tools may diverge an order of magnitude in absolute terms. As a quick survey of load generators by way of those included in Meshery, the differences are noteworthy and justify their use under different circumstances.

Written in C, **wrk2** supports ignoring coordinated omission and provides tests of more complex scenarios. Users express load generation profiles in terms of RPS. Benchmark results may not show what every 1,000th user might see. To see these outliers, you need to run the longer (time) performance tests. Wrk2 tests the scenario where there's a string of services comprising microservices. Wrk2 requires you to specify the desired RPS, while wrk does not. Wrk2 is focused on driving the maximum RPS. Meshery's fork of wrk2 enables testing of multiple endpoints and enables the variable rate of load generation. In the future, Meshery will offer the ability to assign a weight to each endpoint for the load to be generated by wrk2.

Written in Golang, **fortio** [9] is extremely fast and usable for testing basic response times on a per request level. Fortio produces results in JavaScript Object Notation (JSON) on a per request basis and easy to integrate into other Golang-based tooling like Meshery.

Written in C++, **Nighthawk** supports both open- and closed- loop testing, and was designed to offer the right sensitivity for benchmarking microservice proxies (sub millisecond latencies). Using an open loop test methodology avoids coordinated omission, and, in conjunction with its adaptive load controller, one can seek answers to questions like "what RPS can my mesh reliably sustain under set latency?".

It is important to note the power of the service mesh data plane and the cost of that power. Envoy is a popular proxy of choice for service mesh data planes. Among other features, Envoy provides the ability to integrate custom traffic filters via one of two methods:

- Natively by incorporating your custom traffic filter into Envoy's C++ source code and compiling a new Envoy version. The drawback being that you need to maintain your own version of Envoy, while the benefit being that of your custom filter running at native speed.
- Via WASM by incorporating your custom filter as a WebAssembly binary writing in C++, Rust, AssemblyScript or Go. The drawback being that WASM-based filters incur some overhead, while the benefit being that you can dynamically load and reload WASM-based filters in Envoy at runtime.

Whether to integrate your traffic filters natively or as an extension, a tradeoff between the two deployment exists primarily in exchanging between service mesh speed and service mesh flexibility as shown in *Figure 5*.

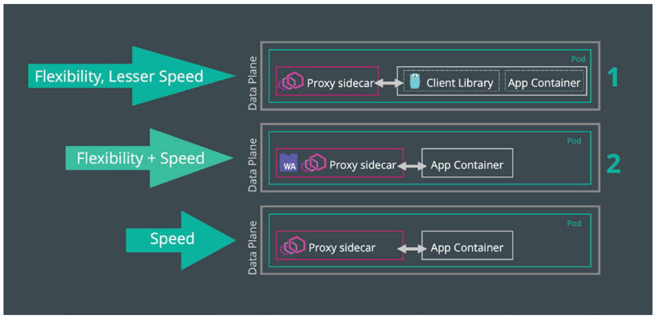

Figure 5: A comparison of different modes of delivery of service mesh network functions.

As an assessment of this tradeoff, Table 1 shows an analysis of two tests run across the same rate limit network function implemented as 1) a Golang-based client library or 2) a Rust-based Envoy filter running in a WebAssembly virtual machine. Users not only need to account for the (relatively) easy to quantify system overhead and the operational overhead involved in expending development resources to implement bespoke tooling versus managing off-the-shelf filters.

Table 1: Comparison of Types of Data Plame Filtering

Implementation Type	**Requests per Second (RPS)**	**Median Latency p50 (50th Percentile)**
Golang-based Client Library	100 RPS	3.19 ms
	500 RPS	2.44 ms
	Unlimited RPS (4,417)	0.066 ms
WebAssembly Virtual Machine (Rust-based Envoy Filter)	100 RPS	2.1 ms
	500 RPS	2.22 ms
	Unlimited RPS (5,781)	0.62 ms

VI. SUMMARY

To deploy a service mesh effectively, we need to quantify application workload characteristics and the utilization of particular microarchitectures; to assess requirements for Container Network Interface (CNI) drivers, Open Virtual Switch (OVS), rules processing, and lookups between Network Address Translated (NAT) and routed networks; to consider different layers of service mesh to be deployed including layer 4 load balancers, ingress and reverse proxy, number of sidecars and number of microservices to be supported; to determine hardware baseline performance for the specific setup; and to set a quantifiable measure of service mesh deployed with performance measures mapped to KPIs like throughput (RPS) and latency.

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Facilitating Satellite-Airborne-Balloon-Terrestrial Integration for Dynamic and Infrastructure-less Networks

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ABSTRACT

This article investigates the potential enhancement of communication networks by integrating ground base stations (GBS) with air stations, such as balloon, airborne, and satellite. The objective is to establish dynamic bi-directional wireless services (i.e., uplink and downlink) for ground users in congested and remote areas. The proposed integration involves satellite, high-altitude platforms (HAPs), and tethered balloons (TBs) in the exosphere, stratosphere, and troposphere, respectively, for better altitude reuse coupled with emerging optical or other high-frequency directional transceivers. This will lead to a significant enhancement in scarce spectrum aggregate efficiency. However, the air stations deployment and resource managements in this integrated system faces difficulties. This article tackles resource management challenges by (i) providing wireless services to ground users in remote areas and connecting them with metropolitan and rural areas and (ii) employing HAPs equipped with free-space-optical communication modules as back-hauling backbones. Finally, we illustrate some numerical results to show the benefit of our proposed integrated system.

Index Terms - Satellite station, high-altitude platforms, tethered balloons, optimization.

I. INTRODUCTION AND MOTIVATION

Satellite and ground base stations (GBSs), also known as terrestrial stations, are currently the main communication systems that provide wireless services to ground users in remote and metropolitan areas. While traditional space communications, including satellite stations, deliver broadband services to ground users in remote areas, their spectral efficiency is constrained because of the high pathloss attenuation of the channel between ground users and satellite station. Depending on satellite stations only can cause extra delay for real time services because of their location at different orbital heights.

In contrast, GBSs cannot support ground users in remote areas due to their limited coverage areas and power unavailability. For this reason, one of the proposed ideas is to integrate the GBSs with satellite stations to improve the total network's capacity and coverage. Satellite stations can use multiple spot beams associated with multiple label switching protocols and spectrum access control [1]. Therefore, satellite stations can communicate with users with the help of GBSs working as relays [1]. In this case, GBSs are used to amplify the communication links between multiple satellite stations and multiple ground users [2]. However, because the satellite stations depend on the terrestrial network to broadcast their signals, this presents another limitation, especially in remote areas and during periods of congestion or network failure.

High-altitude platforms (HAPs) and tethered balloons (TBs) can bridge this gap and provide downlink and uplink services in remote and congested areas. One of the most important elements in the sixth-generation (6G) network is that coverage must be large enough to provide acceptable data- communication services wherever users live, including urban and remote areas. However, 6G networks are not intended to provide equally good service to all areas but rather maintain resource balance [3]. Because of the huge growth in mobile and wireless device usage and immense data traffic, traditional GBSs are expected to face some difficulties in supporting the demands of users in urban areas. This problem can be exacerbated by failures in the ground infrastructure. However, developing a terrestrial infrastructure that provides telecommunication services to remote areas is hardly feasible. To overcome these challenges, integrating the GBSs with higher altitude stations can be a promising solution for reaching global connectivity.

The integration of GBSs, balloons, airborne, and satellite stations into a single wireless network can enhance the overall network throughput. Further, the integration of the four stations would provide reliable, seamless throughput anywhere on Earth. This includes remote, ocean, and mountain areas where the use of optical fiber is limited and costly. Indeed, nowadays only half the world's population has access to the Internet according to recent statistics, and this unconnected population is mostly in the poorest areas of the world where infrastructure is scarce.

HAPs and TBs can work as aerial relay stations to enhance the wireless channel quality between ground users and satellite stations. Thus, they can enhance overall network throughput and help global connectivity with or without the existence of a terrestrial network [4]. The altitude ranges of aerial relay stations are chosen carefully not only to reduce energy consumption, but also to maintain the position stability of HAPs and TBs [5]. This solution can provide immediate wireless connectivity to (i) ground users in remote areas with challenged networks, (ii) on-demand users in congested urban areas with capacity shortages due to peak traffic, such as Olympic games, marathons, or base-station failures, (iii) first responders and victims in emergency or disaster-recovery situations where infrastructure networks are unavailable or disrupted, (iv) ground military in hostile environments, and (v) border-patrol services for patrolling in difficult terrain. The main advantages of deploying HAPs over GBSs can be summarized as [4,5]:

- High coverage range: The GBSs' broadband coverage range is usually much less than the HAPs' range due to high non-line-of-sight (non-LoS) pathloss.
- Dynamic and quick deployment: HAPs have the flexibility of flying to remote or challenging areas to provide on-demand Internet services.
- Low consumed energy: Because HAPs can be equipped with solar power panels, where the energy can be harvested during the daytime, then HAPs can be self- powered with careful trajectory optimization [6].

In turn, the main advantages of HAPs over satellite stations can be summarized as [5]:

- Quick and low-cost deployment: HAPs can be deployed quickly to accommodate traffic/temporal demand, emergency, or disaster-relief applications. One HAP is sufficient to restart the broadband communications services by flying to desired areas in a short, timely manner. Furthermore, the deployment cost of satellite station is much more than HAPs' deployment cost.
- Low propagation delays and strong signals: HAPs can provide broadband Internet services to ground users with less delay than satellite station. This is due to the lower path loss attenuation compared to satellite stations.

Several papers have investigated the HAPs' deployment methods [6,7]. The authors in [7] studied the deployment of the HAPs taking into account the ground users' quality of service (QoS). The work proposed a game theory model based on a self-organized model which maximizes the data rate of ground users. The work considers the HAPs as self-organized and rational players. The authors in [6] proposed some techniques for trajectory optimization where HAPs are equipped with solar panels. The work proposed two solutions based on a heuristic greedy algorithm and real-time and low complexity solution. The objective is to minimize the consumed energy, that is constrained by the harvested energy amount, by optimizing the trajectory of the HAPs. Improving the overall system data rate is also limited by another key factor in this integration system. For instance, the authors in [8] proposed to use orthogonal frequency division multiple access (OFDMA) for multicast technique to optimize the HAPs' transmit powers, transmission time slots, and resource block channels aiming to maximize the total ground user data rate. In other words, they maximized the number of users that received the requested multicast streams within the HAP's service area for a given OFDMA slot frame. The achieved enhancement in multiple HAPs' capacities is discussed in [9], where the authors showed that by exploiting the directionality of user antennas, HAPs can offer spectral efficiency. This work also discussed how multiple HAPs can take the advantages of directionality by sharing the same frequency bandwidth. In a recent work of ours [10], we proposed a downlink resource-allocation solution of integrated satellites, HAPs, and GBSs based on OFDMA to maximize user throughput considering back-hauling and access-link constraints. In another work [11], we proposed using TBs connected with optical fibers as back- hauling stations to support ground users.

Equipping aerial relay stations with free-space-optical (FSO) transceivers is a tipping point. Limited research has proposed equipping aerial relay stations (i.e., HAPs and TBs) with FSO transceivers [12, 13]. The overview of equipping HAPs with optical transmitters has been discussed in [12]. The work shows that several Gbps data throughput can be achieved by using leaser FSO beams. In contrast to this approach, closed form expressions for bit-error-rate and average capacity were derived using multiple hop FSO transmitters in the stratosphere region [13]. However, all the previous works did not consider managing the resource allocations in a satellite-airborne-balloon-terrestrial network integration while maintaining the FSO communication links, nor did they consider issues of back-hauling and access-link communications.

II. INTEGRATION WITH HYBRID FSO/RF

A. Integration of Aerial RelayStations

Deployment of aerial relay stations in remote, large geographical infrastructure-less areas with grid power limitations can be a potential solution to provide wireless uplink and downlink services to ground users as shown in Figure 1. Working as relays or intermediate nodes, aerial stations can maintain the wireless connectivity by broadcasting the uplink and downlink signals. Aerial relay stations not only enhance the uplink and downlink signals but also create a new dimension to next-generation wireless networks and service provisioning. In September 2017, Hurricane Irma (Category 4 Hurricane) hit Florida and damaged a significant percentage of cellular GBSs. For example, in some counties in Miami city, Irma caused more than 50% of GBS failure for days after the hurricane. Additionally, Irma knocked out power to more than 6.8 million people for several days/weeks [14]. In such circumstances, aerial relay stations can reach such affected areas because of their quick and dynamic deployment [15].

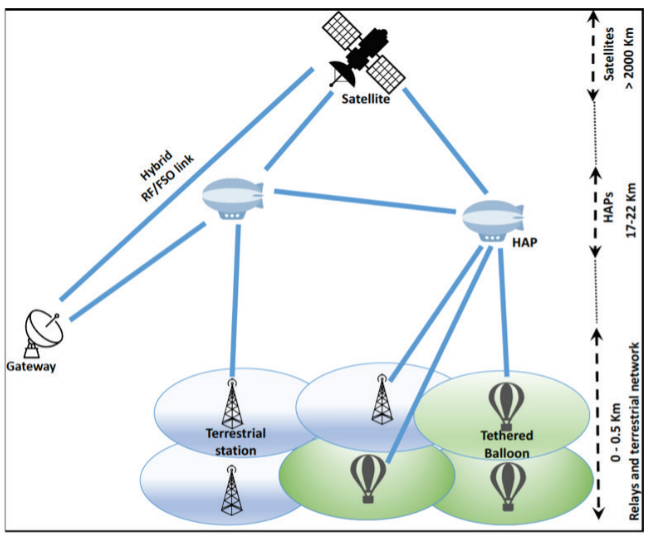


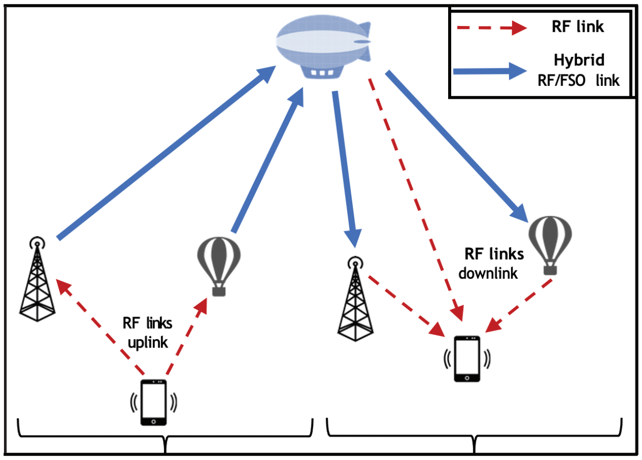
Figure. 1: System model.

The success of deploying aerial relay stations in remote or challenging areas depends mainly on two factors. The first factor is the integration with ground users via access link, while the second factor is the availability and other parameters related to back-hauling links. The efficient placement and resource management of aerial relay stations can generate wireless connectivity in challenging areas. Note that, TBs can be powered by renewable energy (RE) sources, and therefore, can be placed in remote areas to help in uplink and downlink services. This is a plausible proposal since in remote areas, the TBs would consume less energy by serving fewer users. Additionally, some sleeping strategy (i.e., powering on-off the TBs) can be used to reduce the overall energy consumption.

B. Hybrid FSO/RF

Compared to the current wireless networks, the expected next generation wireless demand is ambitious and may require throughput around 1,000 times higher with round-trip latency around 10 times lower [16]. The radio frequency (RF) spectrum is anticipated to be more and more congested for emerging technologies and applications in future wireless networks. Therefore, the RF technology may be insufficient to accommodate the expected increase in the demand of wireless devices. Focusing on improving the RF spectrum only in legacy bands may be not enough, thus it is critical to embrace a comprehensive technology with high spectral reuse by supplementing RF technology with other wireless technologies in directional higher frequency bands [17]. FSO communications is considered as a promising complementary solution with RF to meet the exploding demand for wireless networks. FSO transceivers are amenable to dense integration and provide spatial reuse and security through highly directional beams. RF's huge unlicensed spectrum presents a unique opportunity to overcome the expected future spectrum scarcity problem. Its potential integration with solid-state lighting technology also presents an attractive commercialization possibility [17]. The authors in [18] proposed a vertical framework consisting of networked HAPs that supported back-hauling links and access links of small cell base stations in a multi-tier heterogeneous network. However, that work was limited to supporting small cells, did not consider the integration of all types of GBSs (e.g., macro cell base stations) and satellite stations with HAPs, and did not discuss providing global connectivity in remote areas. This paper focuses on infrastructure-less operation, where the HAPs and TBs are equipped with directional FSO transceivers to provide wireless connectivity for the back- hauling links.

HAP-TB integration offers another dimension to legacy wireless networking by enabling spatial reuse. TBs can effectively amplify the signals between the HAPs and ground users using FSO links without causing any major interference for the rest of the ground users. If this spatial technique is not used and relaying is used only on the RF band, then the aggregated throughput will be limited due to (i) the scarcity of the RF band and (ii) the possibility of interference between HAPs, TBs ,and ground users. Therefore, the potential of using spatial reuse is possible only if HAPs, TBs, and gateways are equipped with FSO directional antennas and their positioning and precision steering of the antennas are feasible. However, the FSO directional transceivers require not only the FSO link establishment, but also line-of-sight maintenance between different transceivers.



- Twopossiblelinksforuplink:throughTB orGBS
- HybridRF/FSOforback-hauling

-Threepossiblelinksfordownlink:through TB,GBS,ordirectHAP
-HybridRF/FSOforback-hauling,ifneeded.

Figure 2: All possible uplinks and downlinks scenarios

III. SYSTEM MODEL

We define the following system model as a hybrid FSO link:

- A set of stations, including a satellite, HAPs, TBs, and GBSs, where each station contains its station ID, 3D lo- cation, battery level at any given time (if applicable, e.g., HAPs and TBs), and back-hauling rate. All this information is shared with some central units. Since the TBs are RE stations, the consumed power during different station states, such as operating and transmission, is included.

- A set of ground users that contain user IDs, two-dimensional locations, and QoS requirements.
- A set of fixed gateways that contain the gateway IDs and two-dimensional locations.

The major challenge is managing the ground users' and stations' resources. The ground users' data rate must be maximized considering the (i) bandwidth and power constraints, (ii) association constraints, and (iii) HAP- and TB-placement constraints. In other words, the ground users' throughput depends on several factors such as the maximum ground users' allowable transmit power, TBs' and HAPs' available bandwidth, and station placement. Therefore, control links between the stations and corresponding users are required to allow stations to track users' locations under its coverage area and manage resources. The utility rate of the system can be characterized by various utility metrics, the selection of which can be based on required fairness levels. Some examples are (i) sum rate utility (maximize the sum rate throughput of all users), (ii) minimum rate utility (maximize the minimum user throughput), and (iii) proportionally fair rate utility (maximize the geometric mean of the data rate).

IV. RESOURCE MANAGEMENT

The key goal is to attain high throughput of ground users and energy efficiency. Several metrics can be implemented to achieve this goal, such as (1) minimizing the total consumed energy while satisfying a certain user's throughput, or (2) maximizing the energy efficiency utility. In this context, several high-level research questions need to be addressed:

- *Resource Optimization:* How to optimize the transmit power allocation of the users and various types of stations and, given a certain available bandwidth, how to allocate this bandwidth for the control links (for management) or serving links (i.e., access and back-hauling links)
- *Associations:* How to configure (a) access link associations (the associations between users and GBSs, TBs, and HAPs) and (b) the back-hauling link associations (the associations of GBSs and TBs with HAPs and between HAPs and gateways), as shown in *Figure 2*.
- *HAPs and TBs Placement:* How to find the best locations for HAPs and TBs considering back-hauling linkquality.
- *FSO Alignment:* How to optimize the FSO alignment angles between different FSO transceivers.

The RF and FSO choices will depend on several factors, such as environmental or weather conditions and the feasibility of LoS. Note that the use of a hybrid FSO/RF link will be for back-hauling links, while the RF band only can be used for the access link due to the difficulties of tracking the movement of ground users and maintaining the LoS, as shown in *Figure 2*.

A. Access Link Optimization

In this work, we propose using multiple stations (i.e., GBSs, RE TBs, and HAPs) to provide wireless connectivity to multiple ground users. Because we involve different types of stations, the access link can be established based on the form of communications. (i) For uplink, two possible links can be established: ground users to GBS or ground users to TBs. (ii) For downlink, three possible links can be established: HAP to ground users, GBS to ground users, or TB to ground users, as shown in the dashed lines in Figure2. In this case, the mathematical formulation should include an access link binary variable to indicate that ground users are associated with certain stations for the specific form of communications (either downlink or uplink). For simplicity, we assume that each user can be associated with one station at most; however, each station can be associated with multiple users. For station peak power and user peak power, an optimization problem can be formulated that maximizes user utility given the following constraints: (i) back-hauling bandwidth and rate, (ii) station and user peak powers, (iii) access link associations, and (iv) user QoS. Therefore, the following parameters can be optimized to achieve the best objective function: (i) the transmit power levels of the user and station transmission power, (ii) bandwidth allocation to each user, and (iii) access link associations.

Other factors can play significant roles in determining the access link associations: first, the back-hauling available rates, where a user can be associated with a distant station if it has a good back-hauling rate rather than being associated with a nearby station with a low back-hauling rate, and second, the energy stored in TBs because they are assumed to be RE battery-powered stations and the amount of stored energy by each TB at the end of a given time slot is considered an additional limitation. In this case, each TB should respect and ensure that the consumed energy is less than the stored energy in the previous time slot.

B. Back-hauling Optimization

In this section, we propose integrating GBSs and TBs with HAPs using hybrid FSO/RF links. A key challenge for networking under partial or no infrastructure is establishing reliable back-hauling links to the TBs or gateways involved in the provisioning of connectivity services for ground users. The back-hauling optimization problem is proposed to optimally find back-hauling associations, HAP locations, transmit powers, and FSO alignment between transceivers to maximize user back-hauling throughput while respecting resource limitations. This involves utilizing high-frequency directional bands, such as optical bands, as much as possible to minimize the interference between transceivers. It is assumed that each HAP is strictly associated to one back-hauling station (i.e., either a gateway station or satellite station). Additionally, we assume a limited number of HAPs associated with the same back-hauling station. For the FSO link between different transceivers, we assume that the alignment angle can be optimized to achieve LoS alignment. In this case, we propose FSO link discovery and establishment. One way is to explore out-of-band techniques where support from an RF or GPS is available to exchange the angle/direction and also exchange information about how they are oriented.

In addition to the HAP back-hauling, back-hauling links between GBSs and TBs with HAPs can be established based on the form of communications. (i) For uplink, two possible links can be established: GBS to HAPs or TBs to HAPs.(ii) For downlink, two possible links can be established: HAP GBSs or HAPs to TBs, as shown in the solid lines in Figure 2. Therefore, another binary decision variable must be introduced for the back-hauling associations.

V. RESULTS AND DISCUSSION

This section provides some numerical results to outline the benefits of using our proposed integration to improve global connectivity. The numerical results setup is within an area of 180km x 180km. We distribute U ground users in this area in three different sub-areas: (i) sub-area A of 70km x 70km, (ii) sub-area B of 70km x 70 km, and (iii) sub-area C, the remaining area. We also consider different users' density distributions in each sub-area, as shown in Figure 3. Sub-area A contains 30 GBSs with x and y ranges as (x:55–125km) and (y: 0–70 km), respectively. It contains 40% of total number of ground users. Subarea B has no GBSs with x and y ranges as (x:55–125km) and (y:110–180km), respectively. It contains 30% of total number of ground users. Sub-area C is the remaining area. Further, the total number of TBs and HAPs used are 30 and 8, respectively, as given in Table I.

We study the enhancement of the achievable downlink and uplink throughput when HAPs and TBs assist the terrestrial network. We also consider different back-hauling bandwidth cases to represent both RF-only and hybrid FSO/RF scenarios to investigate the limitation of the RF-only scenario.

Table I: Simulation parameters

	Sub-area A	**Sub-area B**	**Sub-area C**
Sub-area (Km × Km)	70 × 70	70 × 70	Remaining
Dimensions (Km)	[x:55-125], [y:0-70]	[x:55-125], [y:110-180]	Remaining
Users distribution (%)	40	30	30
Number of TBSs	30	0	0
Example	City area	After disaster area	Rural area

The results in this section are based on optimizing the station placement (i.e., HAPs and TBs) and the associations (access and back-hauling associations). For stations placements, we use a heuristic shrink-and-realign algorithm to find the optimal placement. The shrink-and-realign algorithm has several benefits compared to other heuristic algorithms in the literature: (i) it has a simple implementation, (ii) it is considered as low complexity algorithm, and (ii) it is very fast with quick convergence. The algorithm starts by generating initial next candidate positions as spheres around the current position before recursively shrinking the sphere radius by half to find the best local position and compare it to the current position. The algorithm repeats the above process until the sample space size decreases below a specific limit or no enhancement can be made. For resource allocations, we formulate a linear and convex optimization problems for solving the associations and power allocations based on OFDMA.

Figure 4 plots the achievable average uplink data rate as a function of transmit power of ground user. The average uplink data rate is per ground user and equals to the sum of the total uplink throughput divided by the total number of ground users. This figure compares our proposed integration model with two baseline models. The satellite station is only used for the uplink transmission, or the satellite and multiple HAPs are used only (i.e., TBs are excluded) for the uplink transmission. It is shown that our integrated system achieves a higher uplink throughput compares to the two baselines. For example, when the ground user transmitted power is equal to 20dBm, the achievable uplink throughput can be improved from around 0.3 Kbits/sec for satellite only solution and 0.3 Mbits/sec for satellite and HAPs only to around 3 Mbits/sec by using the proposed integrated system. This is due to TBs that can help in broadcasting the uplink signal and mitigating the pathloss and other unfavorite effects. Further, from the same figure we can show that the average ground users throughput of proposed integrated system and satellite and HAPs only increases as the ground transmit power increases up to a specific value (~40 dBm) After this value, the performance remains constant. This is because of the back-handing limitation in the relay link from TBs to HAPs.

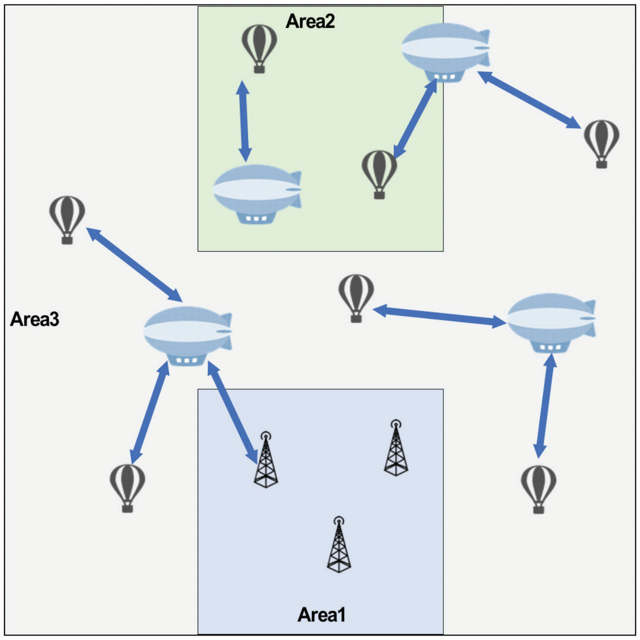


Figure 3: Simulation Setup

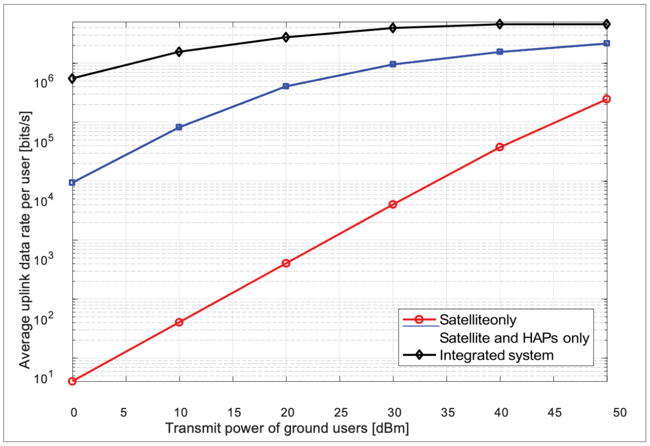


Figure 4: Average uplink data rate versus ground user's transmit power.

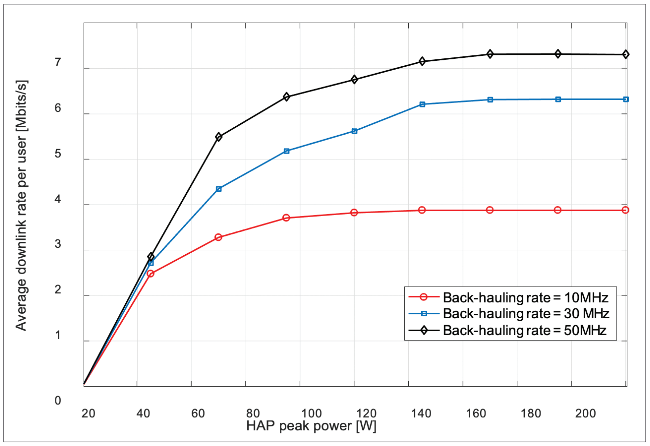


Figure 5: Average downlink data rate versus HAPs' peak power.

To illustrate the FSO/RF back-hauling bottleneck effects, Figure 5 illustrates the average downlink throughput as a function of HAPs peak transmit power. It can be seen that as the downlink data rate increases as HAPs' peak transmit power rises up to a certain value. This is because, by starting from this value, the average downlink throughput cannot be improved. This is due to the limitation of the back-hauling link from HAPs to gateways or HAPs to satellite links. Further, it can be seen that the average downlink throughput increases as back-hauling bandwidth raises. This is because increasing the back-hauling bandwidth also increases the back-hauling data rate capacity, thus increasing the back-haulingbottleneck. Therefore, hybrid FSO/RF communication links can be used to mitigate back-hauling bottleneck limitations and thus enhance the overall performance.

VI. CONCLUSION

This paper proposes an efficient scheme that integrates GBSs, TBs, HAPs, and satellite stations to provide global connectivity. Our objective is to improve downlink and uplink rates by optimizing back-hauling and access links. We also proposed equipping the stations with FSO transceivers to mitigate the back-hauling bottleneck limitation as shown in the simulation result section and therefore improve the data rate. In contract, this needs more effort in optimizing extra variables such as line-of-sight angles.

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IEEE Communications Society—Connecting Engineers Who Connect the World

By Ricardo Veiga, Director, Membership Services Board, IEEE Communications Society

"The world would have been different this past year without the research, work, and innovation driven by our members." That's a simple statement that shows the value of each contribution, each opinion, each piece of research, and each piece of technology our members helped create.

The IEEE Communications Society (ComSoc) promotes technological innovation and fosters creation and sharing of information among the global technical community. But it's more than that.

We are called to communications technology. Our reasons and regions may be widely different, but our goal is the same: To advance communications and networking technology for the betterment of humanity. Our vision is to bring the world together in harmony through communications and networking technology research, application, education, and incubation of new ideas.

Discover the Latest

Discover the latest breakthroughs, cutting-edge information and research on communications technologies with access to diverse ComSoc magazines, journals and conferences.

Considered by many to be their most important member benefit, IEEE Communications Magazine serves as the industry's single most important source of state-of-the-science communications information. The latest issue of this monthly magazine covers hot topics like the cover story, *5G for Verticals: From Theory to Practice and Beyond, and has a series on Mobile Communications and Networks.*

Connect and Collaborate

Exceptional networking opportunities and over 200 local chapters worldwide allow members the opportunity to connect, collaborate, learn, and celebrate accomplishments. As an example, the IEEE ComSoc Panama chapter recently celebrated members who made outstanding contributions in telecommunications in relation to COVID-19 recognizing them with two new awards.

In response to the pandemic, chapters successfully pivoted to leverage networking and learning opportunities by connecting with other local chapters around the globe to offer leading-edge technical education sessions delivered by renowned communications technology experts via ComSoc's virtual Distinguished Lecturer Program.

Learn & Get Ahead

World-class training, certification programs, and technical committees offer the chance to advance your career or education in communications by staying on top of current communications technology topics. Our school series is perfect for students and Young Professionals to help kick-start the careers of new professionals, Ph.D. candidates, and researchers in wireless communications.

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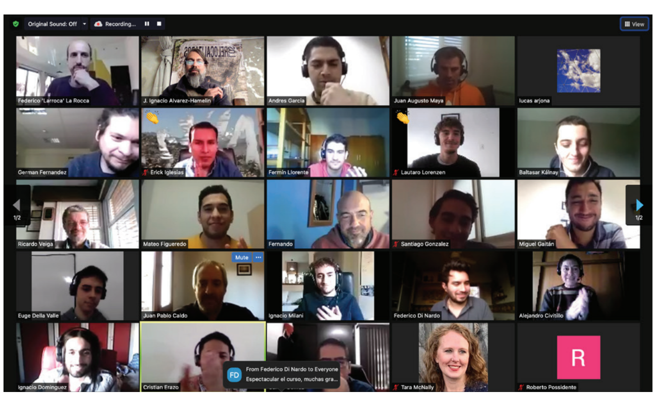
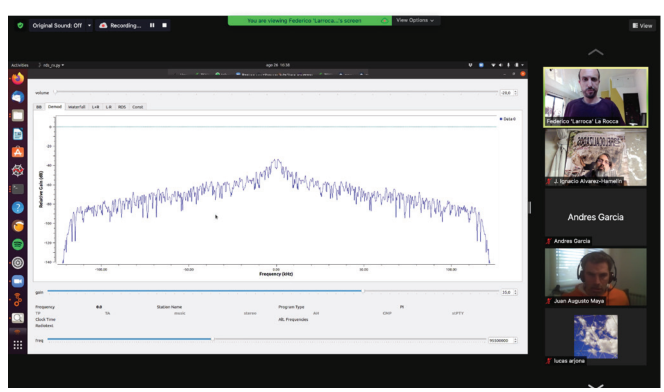




Attendees at IEEE ComSoc School Series Buenos Aires gather online to learn about "The Present and Future of Communications and Their Applications: 5G and Beyond."

Celebrating the Research Contributions of Our Graduate Student Members

An important and growing part of IEEE-HKN's global community, Graduate Students are performing groundbreaking research. We have developed a new section in *THE BRIDGE* intended to celebrate and elevate their research contributions. The HKN Graduate Student Research Spotlight will be a standing feature in *THE BRIDGE* through 2022. The profiles of the students and their work also will be shared on our social media channels.

Each profile will showcase the intellectual merit and broader impacts of HKN graduate student members' research, and provide information about the student's background and where people can learn more.

We will spotlight these achievements while also showing potential graduate students what is possible!

Would you like to be featured?

Fill out our submission form. Submissions will be reviewed, assembled into a profile template, and posted on HKN's social media pages. A select number of profiles will also be featured in *THE BRIDGE*.

New Advertising Opportunity

IEEE-HKN is the professional home to the world's top Graduate Students in Electrical and Computer Engineering, Computer Science and the allied fields of interest. Get your company or university in front of these students and HKN's undergraduate students who are considering their next steps by advertising in a special section in *THE BRIDGE*. Click here for more information and rates.

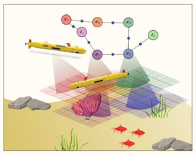
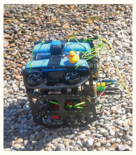
Kevin Doherty

Iota Delta, Massachusetts Institute of Technology,
Ph.D. Student in Aeronautics/Astronautics and Ocean Engineering

RESEARCH TOPIC
Robust Object-Based Robot Navigation

Increasingly, robots are deployed with the capabilities not just to measure distances to obstacles using cameras, sonar, and lidars, but, through recent advances in machine learning techniques, to also detect and classify objects in the scene and perform other high-level perception tasks. We expect a robot to know not only where it is and where the obstacles are, but also what those obstacles are. Combining this semantic information with the geometric information that robots typically use to build maps is challenging because present techniques for object recognition often fail in unfamiliar environments. Moreover, even when these systems perform perfectly, ambiguous scenes can make navigation a challenge. Likewise, we as humans might walk around an unfamiliar area and think "is this the same building I saw before?"

Kevin's work, supported by an NSF Graduate Research Fellowship, is centered on the problem of building algorithms or robots to combine object-level information with geometric information during navigation, while being robust to the inevitable failures that come with long-term operation. A major focus of this work has been on enabling robots to efficiently keep multiple hypotheses about the state of the world; e.g. "this could be the building I saw before, or it might not be." This work is particularly targeted toward marine robotics, where sensing is often limited and natural features are repetitive or sparse, so reasoning about ambiguity is critical.


Top left: Illustrated example of an underwater vehicle performing object-based mapping (x: robot poses, l: object landmark). Top right and bottom: Mapping pilings with the BlueROV2 underwater robot in Woods Hole, MA.

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https://scholar.google.com/citations?user=IYPhbO0AAAAJ&hl=en

CONTACT
https://people.csail.mit.edu/kdoherty/

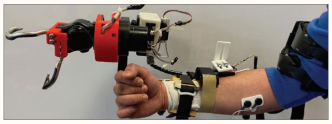
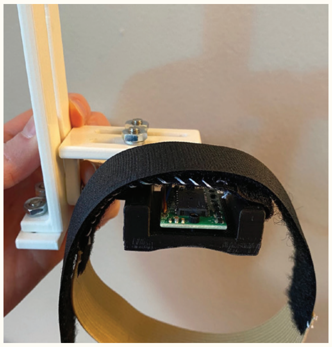
Fiona Popp

Beta Eta, North Carolina State University, M.S. in Electrical Engineering

RESEARCH TOPIC
Novel Optical Sensor System for Prosthetic Wrist Rotation Control

Conventional prosthetic wrist control utilizes electromyography (EMG) signals. The two main EMG control methods are Direct Control (DC) and Pattern Recognition (PR). DC uses an agonist/antagonist muscle pair to control the direction of one Degree of Freedom (DOF) at a time. Contracting both muscles allows the user to consecutively switch through the DOFs. PR trains a classifier based on the EMG signals when performing different arm/hand postures. Both of these methods impart challenges on the user. DC is unintuitive because the user must consecutively switch between the DOFs. PR has challenges with robustness due to inconsistent EMG signals from skin impedance, electrode shift, and fatigue, which cause misclassifications.

Fiona's research, supported by a National Science Foundation grant, consisted of developing and evaluating a novel sensor system for wrist rotation control. The system utilized an optical displacement sensor, commonly used in computer mice, to monitor the position of an able-bodied individual's forearm. The speed and direction of the prosthetic wrist, mounted on an able-bodied prosthesis adapter, was controlled based on the approximated position from the optical sensor. This system allows for simultaneous control of 2 DOF, when utilizing the optical sensor for pronation/supination and EMG control for hand open/close. Additionally, it has the potential of being more intuitive than DC, more robust than PR, and allow for faster task completion time.

Prosthesis setup and 3D printed adjustable mount with sensor.

LEARN MORE
https://repository.lib.ncsu.edu/handle/1840.20/38600

CONTACT
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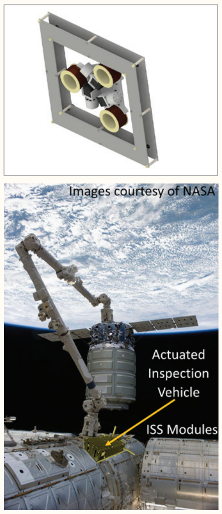
Katherine Wilson

Omicron, Cornell University, University of Minnesota - Twin Cities
Ph.D. Candidate in Aerospace Engineering, NASA Space Technology Research Fellow

RESEARCH TOPIC

Propellant-free, Non-contact Electromagnetic Actuation for Microgravity



The International Space Station (ISS), proposed Lunar Gateway, and other space infrastructure require routine servicing. Propellant-free methods for extravehicular maintenance facilitate autonomous or remote tasks, reduce launch costs for propellant and avoid plume contact with sensitive instruments. Potential client spacecraft, including the ISS, have conductive surfaces due to orbital debris shielding. These surfaces facilitate use of forces due to time-varying magnetic fields (i.e., from induced eddy currents) produced by magnets and electric fields produced by electrostatic actuators. This research combines electrical and aerospace engineering perspectives to develop sustainable, non-contact actuation methods for servicing vehicles to move relative to and manipulate client spacecraft. As a NASA Space Technology Research Fellow, Katherine has mentored two undergraduate engineering students through this research to facilitate interest in mechatronics for space robotics and microgravity actuation.

Bottom: This research concept figure shows a microgravity free flyer in gold using an electromagnetic actuator array facing the conductive surface of the International Space Station. Top: An actuator array that combines eddy-current actuators (permanent magnet rotors and AC electromagnets) with an electrostatic actuator (plate) provides 6-degree-of-freedom relative mobility for an inspection vehicle.

LEARN MORE
https://www.spacecraftresearch.com/eddycurrent-actuation

Behnam Pouya

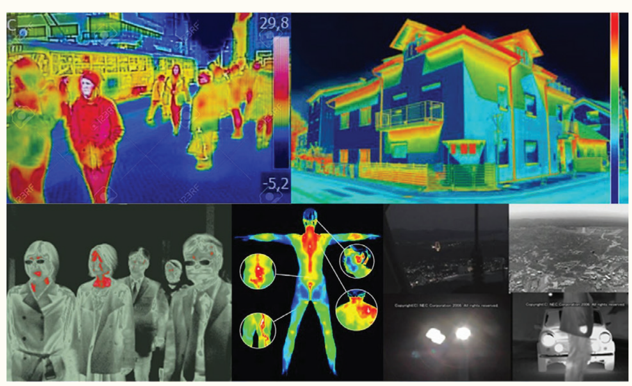
Kappa Kappa, University of Texas at Dallas, Ph.D. Candidate in Electrical Engineering

RESEARCH TOPIC

Far Infrared Detection in CMOS Technologies

Doing his PhD at the University of Texas at Dallas in the Texas Analog Center of Excellence (TXACE) with Dr. Kenneth O, Behnam is working on bridging the so called "THz Gap" of the EM spectrum using CMOS technology. He is trying to push the CMOS imaging limit toward 40 THz. Along the way, novel structures with an ultra-high cut-off frequency in excess of 5 THz were fabricated, measured, and characterized in CMOS without any process modification.

The electronic signal detection using CMOS would help realize the true potential of THz CMOS with countless applications ranging from early-cancer detection to night-vision. It can also be used in airports for detection of viral infections including N1H1 virus (known as swine flu), SARS, bird flu, COVID-19, and any kind of diseases with fever as a symptom.



Applications of FIR EM waves. (Top-Left) People head-counting in the day and night. (Top-Right) Building thermal inspection for efficiency. (Bottom-Left) Pandemic flu countermeasure. (Bottom-Center) Early detection of body tissue damage. (Bottom-Right) Pedestrian detection at night and seeing through smoke/fog for automotive radar system.

LEARN MORE
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Luz-Maria Sanchez Reyes

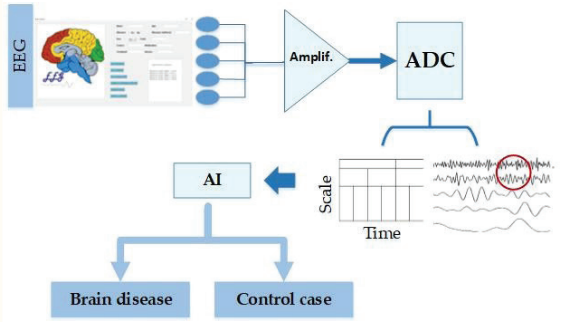
Mu Psi, Autonomous University of Queretaro, Ph.D. Student in Engineering

RESEARCH TOPIC

Non-invasive Biomedical Tools for the Detection of Brain Diseases

Dementia diseases, such as Alzheimer's, are the main cause of disability and dependency in older adults. The number of cases of these diseases is expected to double by 2030 and triple by 2050, which has become an alarming problem for the health sector. Cognitive impairment (CI), a decline in cognitive functions, is one of the first symptoms in the appearance of dementia diseases. This is why with the detection of CI, an early detection of the disease could be achieved. The information offered by the electroencephalogram (EEG), a record of bioelectrical activity, is clinically relevant for the detection of brain diseases and their symptoms. EEG in combination with signal processing, feature extraction, and Artificial Intelligence (AI) classifiers can achieve biomarker identification for automatic detection with high levels of efficiency and fast response.

Luz Maria's work, supported by the Universidad de Querétaro, the Universidad de Baja California, and Concordia University, has developed auxiliary tools for the timely and efficient detection of brain diseases using EEG information, signal processing, and AI. She has also developed a non-invasive device for melanoma detection using image processing, a tool for the automatic process in the synthesis of liposomes, and applications in the area of robotics and renewable energy. She has collaborations with more than 4 universities in Mexico and Canada.



Steps of the process for automatic detection of brain diseases using EEG

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https://www.researchgate.net/profile/Luz-Maria-Reyes

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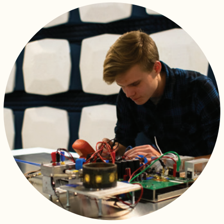
https://www.linkedin.com/in/luz-mar%C3%ADa-s-814b4011b/



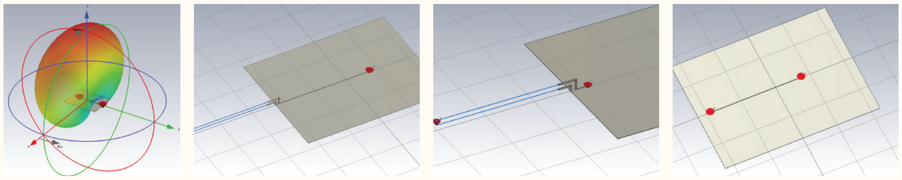
James Hunter

Gamma Theta, Missouri University of Science and Technology, Ph.D. Student in Electrical Engineering

RESEARCH TOPIC

Characterization of Electromagnetic Coupling to Electronic Devices

The electromagnetic susceptibility of electronic devices varies substantially from one device to another. James's work aims to characterize coupling to printed circuit boards (PCBs) and their attached cables, with a goal of understanding when and why a device is most susceptible, as well as how to handle that susceptibility. The characteristic of the coupled voltage can be radically altered by the typical variations seen in these devices, such as the length of the wiring harness, the size of connectors on the device, the size of the PCB board, trace locations, etc. The coupled voltage also depends on the frequency, angle of arrival, and polarization of the incident electromagnetic wave. James has developed an approach to rapidly estimate the electromagnetic coupling to wiring harnesses and PCB traces. By separating a complete device into separate components, e.g. the PCB, connectors, harnesses, etc., and characterizing each "block" individually, a much more flexible model can be constructed. By cascading these blocks together, in much the way that Legos are assembled to build bigger structures, a much wider variety of devices can be studied than by modeling each structure individually. Simulations of the far-field radiation patterns of the models are used to find the statistical characteristics of the coupled voltage while considering the variations in the incident wave and the device itself.



From left to right: 1. Farfield radiation pattern of a simple 2. A simple complete device created by cascading a trace, two pin connector, and parallel wire harness. 3. Segment 1: PCB with trace. 4. Segment 2: Connector and parallel wire combination.

LEARN MORE
https://emclab.mst.edu/

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jdhzg8@umsystem.edu

Sabrina Helbig

IEEE-HKN Beta Delta Chapter University of Pittsburgh, BSEE 2020, MSEE 2022

Sabrina Helbig began her graduate studies in January 2021 at the University of Pittsburgh for a Master's in Electrical Engineering with a focus on power electronics. Her professional and academic interests include renewable energy and resilient power systems, and she finds meteorology and mass transportation to be quite interesting. During her undergraduate experience, Sabrina completed an internship with Westinghouse Nuclear and three rotations of co-op with Eaton. This past summer, she completed an internship with Eaton in its power electronics R&D group outside of Milwaukee, WI. Sabrina is active in many clubs and organizations: She is the current Treasurer and Corresponding Secretary of the IEEE-HKN Beta Delta Chapter, for which she previously served as President, Vice President, and Recording Secretary. She is the IEEE PES-PELS student chapter Vice President at the University of Pittsburgh, and is a member of the Society of Women Engineers. Sabrina is the recipient of the 2021 IEEE Charles LeGeyt Fortescue Scholarship and the 2020-21 IEEE Power & Energy Society Scholar, and was named an Anne-Marie Sahazizian Scholar by IEEE PES. She published a paper with her senior design team for the 2021 American Society of Engineering Education (ASEE) conference. She has studied abroad in France, China, and Scandinavia. Hobbies include traveling and learning about languages and cultures; running 5Ks and 10Ks, yoga, poetry, photography, snowboarding, food, and volunteering.

Why did you choose to study electrical engineering?

I first encountered electrical engineering in eighth grade in our pre-engineering class. Building circuits from schematics, I immediately thought, "This is so cool! Give me more circuits to work on!" Throughout middle school and high school, I learned about how engineering applies principles of math, science, and (as I later discovered) creativity to solve complex real-world problems. Engineering, especially the electrical domain, struck me as incredibly interesting. Plus, I liked the notion that I could help and serve people as an engineer. Further, a two-week study abroad program in Scandinavia, called Clean Energy Grid Engineering, exposed me to Scandinavia's holistic integration of renewable energy, power system considerations, electrical specifications and interconnections, and social, political, and economic ramifications. Since that adventure, I decided to foray into electric power, with particular interest in renewable energy and resilient grids.

During her semester abroad in Scotland, Sabrina climbed to the top of Arthur's Seat in Edinburgh.

What do you love about engineering?

I love the variety of fields, industries, and applications that an engineer can have a hand in and their dynamic evolution; engineers have a measure of mobility in the opportunities that they can pursue, and there is always something new to learn, design, improve, or apply. Additionally, I love the challenge: Engineering in any discipline or domain is not an easy feat, and while it can be cumbersome to grapple with the challenges posed by personal, professional, and technical development, the prospects for discovering something new or different, working through unexpected problems and intricate technical interdependencies, and growing along the way are incredibly exciting.

What don't you like about engineering?

I don't quite like when something goes wrong unexpectedly without a discernable explanation – it can be a very amusing circumstance, but also a frustrating situation. For example, during my sophomore year of college, I built a circuit using a few logic ICs for my digital systems lab. Although I had verified that the circuit design should work and the physical circuit was wired correctly, my output was incorrect. After some troubleshooting, I isolated the problem to a signal that one of the IC chips was receiving – the value was too low for the chip to register it as a high logic value. Great, but after more troubleshooting, I still had no idea why this was happening. You know what worked? The fundamental principle of troubleshooting: unplugging the chip and plugging it back in. Yet, I still have no idea why it wasn't working in the first place.

What is your dream job?

I have not yet determined a specific "dream job," but over the years I have been figuring out which paths seem the most intriguing and fulfilling to me. At this time, I am heavily leaning toward design or research-and-development-oriented careers in power engineering, with a focus on renewable energy and resilient power grids.

Whom do you admire (professionally and/or personally) and why?

There are a number of people among my family and friends, colleagues, and connections that I admire for different reasons, but to highlight one, I greatly admire my PES mentor John McDonald, P.E. (IEEE-HKN Beta Chapter), because he is intelligent, generous, and genuine. On top of that, he is very involved in the organizations and communities that he is a part of, all while making time for his family, friends, mentees, and hobbies (like working out and running 5Ks!).

In what direction do you think engineering and other IEEE fields of interest are headed in the next 10 years?

I think that there will be a lot of new and continued electrification, digitization, and automation and additional movement toward what we can replace or enhance with electronics. In the power fields specifically, envisioning and catalyzing the evolution of the power grid still has great potential as well as many unanswered questions related to the integration of new energy sources and grid topologies, performance and maintenance automation and data analytics, control and optimization of power system operations, and efficiency and capabilities of components, sources, and power conversion.

Sabrina studied Clean Energy Grid Engineering in Scandinavia, during which she toured a waste-to-energy facility that supports electricity and district heating in a Swedish town.

What is the most important thing you've learned in school?

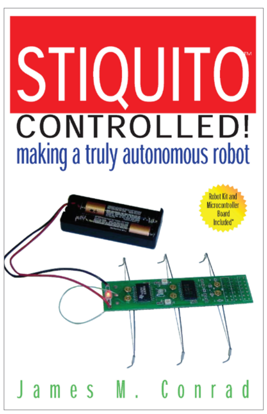
Two of the most important things that I learned in school, besides technical content relevant to my interests and direction in power engineering, is asking for help and learning with the objective of understanding. Asking for help has long been a struggle for me because I often feel that I need to be able to figure out or do something myself. Over time, I realized that asking for help when I am curious or stuck can be a great learning opportunity and can assist me in completing my work more efficiently. As for learning to understand, to me, it is one thing to learn something enough to regurgitate it, but I feel much more accomplished and the knowledge feels much more useful if I can learn it well enough to understand what the topic is all about, how it works, and what can I do with it.

What advice would you give to other students entering college and considering studying your major?

Electrical engineering is not easy – you can't just see an electron roving about a circuit – but it is worthwhile with boundless variety. Ask questions when you are stuck (or if you are curious!), learn how to operate as part of a team (especially an interdisciplinary team), leverage resources for personal, professional, and technical development, and seek opportunities to practice soft skills. It is important to do well in school, but it is just as important to take care of your health and well-being too (read: please sleep). Also, there will be students who breeze through a curriculum and make it look easy. For some of those students, it isn't as easy for them as they make it look. Regardless, if you find the major interesting and you really want to be there, be there – it may not feel easy, it may not be easy, but you're plenty capable.

Jim Conrad

IEEE-HKN President 2022, Beta Eta Chapter ECE Professor, UNC at Charlotte



James M. Conrad received his bachelor's degree in computer science from the University of Illinois, Urbana, and his master's and doctorate degrees in computer engineering from North Carolina State University. He is currently a professor at the University of North Carolina at Charlotte. He has served as an assistant professor at the University of Arkansas and as an instructor at North Carolina State University. He has also worked at IBM, Ericsson/Sony Ericsson, and BPM Technology. Dr. Conrad is a Professional Engineer, a Senior Member of the IEEE and a Certified Project Management Professional (PMP). He served on the IEEE Board of Directors as Region 3 director for 2016-2017, and again as a director in 2020, when he also served as IEEE-USA President. He is the author of numerous books, book chapters, journal articles, and conference papers in the areas of embedded systems, robotics, parallel processing, and engineering education.

Why did you choose to study the engineering field (or the field you studied)?

I started in Computer Science since I enjoyed programming that I learning in a high school class (unusual for 1976!). I gravitated to computer engineering after I started working at IBM and enjoyed controlling hardware with software.

What do you love about engineering?

In computer engineering you can see immediate results of your (correct) programming and hardware work. If you did it well, things move/blink/measure. If you did not do it well, then some parts of the hardware (which you can look at) may not operate well . . . or at all! This is especially evident if you control robot devices, which is where I currently work.

Who do you admire and why?

I admire some of the early pioneers in computer processor and chip technology: Andy Groves, Gordon Moore. They realized the full potential of the heart of many (most?) devices we use every day, and saw how microprocessors and microcontrollers would be so prevalent today.

How has the engineering field changed since you entered it?

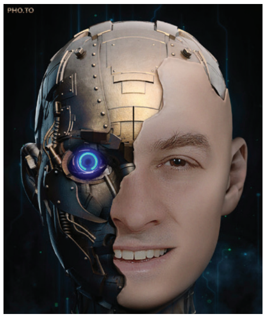
Everything is smaller, faster, cheaper, but more complex. I often tell the story of my first PC purchase in 1985—I bought a $6000 IBM PC-AT (at the employee price of $3000) that had 640k bytes of RAM, a 20 Megabyte hard drive, and ran at 6 MHz. I'm sure all of the readers will realize how big, slow, and expensive that computer was compared to today's laptops, or even tablets.

In what direction do you think that the engineering and other IEEE fields of interest are headed in the next 10 years?

Our products and systems will need a more broadly-knowledgeable team to better meet the functional goals. That means the team will need more diversity (gender, experiences, educational disciplines). The past silos of computer engineers work in this team over here and mechanical engineers work in that team waaaay over there will be gone, and each team member will have skills from two or more different disciplines.

What is the most important lesson you have learned during your time in the field?

People do the work, so you need to know how to communicate well. You must write clearly, present often, and work in a team to be successful. This is becoming more important every year, despite that crazy COVID sequestration we went through.



What advice can you offer recent graduates entering the field?

You must keep learning every day—new skills, new technologies, new processes. Make sure you make IEEE your professional home AND BE AN ACTIVE VOLUNTEER. You will learn a lot of people skills as a volunteer that will translate directly to success in your regular job.

What is your favorite Eta Kappa Nu memory?

This is more recent—it is attending two IEEE-HKN Student Leadership Conferences (in 2018 and 2019) and seeing how the students were so engaged in their chapters and in meeting other student leaders from other campuses. I look forward to when we can have an IEEE-HKN Student Leadership Conference in person in . . . 2022!?!?

Why do you support IEEE-HKN?

IEEE-HKN student members are the best and brightest, and often the most devoted to serving others. I want to ensure that my financial support of IEEE-HKN gives these students the opportunity to learn more than math, electronics and programming. I want to make sure they learn how important it is to serve their profession and their communities.

What are the greatest opportunities for IEEE-HKN over the next three years?

Graduate student members of IEEE do not have a lot of opportunities to participate in activities with other Graduate students across the world. I would like to create a professional home for all graduate students in IEEE-HKN so that they can interact with each other, present their work to each other, and learn leadership skills that will help them land their dream job once they graduate.

IEEE-HKN Celebrates 117 Years!

Founders Day is a way for us to share the IEEE-Eta Kappa Nu story, raise awareness of the value that an IEEE-HKN Chapter brings to a University, show the many ways a Chapter serves fellow students and the community, and encourage industry to support us. Please find a way to tell the IEEE-HKN story to celebrate Founders Day, wherever you are in your IEEE-HKN journey!

- Invite alumni to get involved in your Founders Day celebration. Alumni reconnect with your Chapter.
- Share an HKN memory–tag us: #IamHKN, #HKNFOUNDERSDAY, @IEEE_EtaKappaNu
- Add your HKN status to your social media profiles
- Host or participate in a community service activity
- Hold a networking event
- **Donate to IEEE-HKN** to help us provide Chapter support, training, conferences, special events, and more

Robert A. "Bob" Dent

IEEE Life Senior Member
Eta Chapter

> "I want to pay forward to programs that benefit present and future electrical engineers and society, in general."

You can choose to directly [support IEEE-HKN] or any of the strategically identified IEEE initiatives that help meet the world's most pressing challenges and help us to realize the full potential of IEEE.

Recipient of AFP-New Jersey's Excellence in Philanthropy Award for Outstanding Philanthropist

IEEE Life Senior Member Robert A. "Bob" Dent has won AFP-New Jersey's Excellence in Philanthropy Award for Outstanding Philanthropist for his philanthropy to IEEE through the IEEE Foundation.

Since 1981, AFP NJ's Excellence in Philanthropy Awards have recognized the achievements of some of the most notable citizens and organizations in the State who have dedicated their efforts toward making New Jersey a better place.

Bob, a member of the Eta Chapter embodies the philanthropic spirit and emanates a strong desire to personally "give back" to IEEE and his community. Bob is a champion in providing funding opportunities in avenues of monthly giving, matching gifts, leadership giving, and planned giving. He is a member of the IEEE Goldsmith Legacy League (Planned Giving) and of the IEEE Heritage Circle (Annual Giving).

Bob's volunteer work with IEEE started when he joined the Student Branch of IEEE in 1965 while he was a senior at Stevens Institute of Technology in Hoboken, NJ, USA.

Bob says, "IEEE provided an opportunity to read and hear technical information, to develop professionally, and to network with my peers in the profession and the industry in which I had chosen to work."

After 32 years of volunteering for IEEE, he joined the staff of IEEE as the Executive Director of the Power Engineering Society, now known as the Power & Energy Society (PES). He has served in many volunteer roles within IEEE and has been a leading donor to all of the programs he has been associated with, including the IEEE Smart Village, the IEEE History Center, IEEE SSIT and Eta Kappa Nu.

He says, "I want to pay forward to programs that benefit present and future electrical engineers and society, in general."

Tune in to IEEE-HKN's Newest Offerings: 'HKN Connection' and 'Career Conversations' Podcasts and 'Grad Lab' Webinar Series

IEEE-Eta Kappa Nu (IEEE-HKN) has created one program to tell and spread the unique story of what it means to be a member, another program aimed at assisting graduate students through the challenges of pursuing an advanced degree, and a third program to help young professionals navigate the early years of their careers.

IEEE-HKN has introduced a podcast that gives behind-the-scenes access to the honor society from those who know it best: our volunteers, staff, and partners. Twelve episodes of the 'HKN Connection' are available now on the IEEE-HKN YouTube channel. Topics range from starting or reinvigorating a Chapter to global mentorship, engaging with K-12 students for STEM education, and philanthropy. Tune in to learn more about our global society.

Join us for our new monthly 'Grad Lab' webinar series, in which 2019 IEEE-HKN President Dr. Karen Panetta tackles the unique challenges graduate students face and gives them the tools they need to succeed. The first two episodes, "Survive and Thrive: Tips for the First Semester" and "How to Find a Research Topic" are available to watch on demand.

In November, the "Career Conversations" for young professionals will be added to IEEE-HKN's ever-expanding YouTube channel.

Check out these new offerings and tell us what you would like to see and hear.

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continued from page 31

Students - Making the Mark!
Students are the lifeblood of our organization as they are the future of technology and communications leadership. As you are starting off in your communications path, ComSoc can offer you all that is listed above but more for students:

- ComSoc Student Competition
- Scholarships and awards
- Access to funds via ComSoc Student Travel Grants to conferences
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- Networking and leadership opportunities via Local Student Branch Chapters, Sections, and Regions
- Access to experts, practitioners, industry leaders and the world's top academic researchers

Be Part of the Future
Nearly 30,000 global communications technology engineers, enthusiasts, educators, learners, leaders, and collaborators, connecting to share expertise, learn, and collaborate to solve today's challenges and create tomorrow's improved capabilities. Whether you are a student, Young Professional, or veteran engineer, ComSoc can open doors for your career, research, and help you remain relevant.

Try Us!
IEEE professional members who register for the 2021 Global Communications Conference, GLOBECOM, (hybrid virtual and in-person in Madrid, Spain) can redeem a promo code to add-on complimentary 2022 ComSoc membership, a US $33 value.

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Volume 2 of the Tesla Twins Comic Book Now Available

by Georgia C. Stelluto

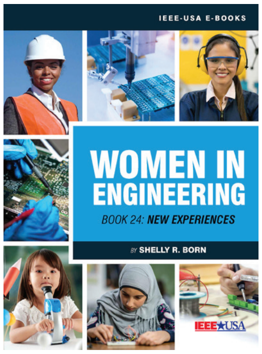
Also: A New Women in Engineering E-Book; A New E-Book on Problem-Solving Critical Thinking Skills; and New Audiobooks on Boosting Team Creativity and Caring for Your Project Team.

Check out IEEE-USA's excellent new e-books and audiobooks for students, members and educators – all free to all IEEE members.

Here are the latest new IEEE-USA E-Books:

The Tesla Twins: Rescue at the Speed of Light is Volume 2, and the latest in the comic book series IEEE-USA launched last year. The first comic book was ***The Slate Twins: Caught in the Currents***. This new issue continues the adventures of the Tesla Twins as they fight a new evil villain, Count Mario Ingannamorte (Translation: Cheat Death), billionaire owner of Mega Tech, and former foe, Buck Gains, as the Twins try to rescue their long-lost parents.

Comic book Author Jeff Knurek creatively intertwines the theories of Nicola Tesla, Albert Einstein, and Stephen Hawking into this new adventure. Don't miss this new edition – free to all IEEE members. It's a fun read with some history and education mixed in. Great for all IEEE members – young and old!

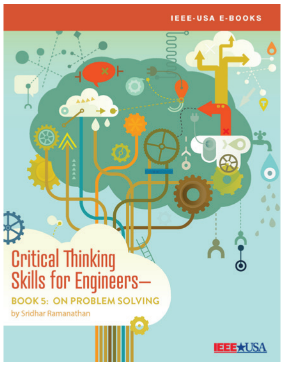


Women in Engineering—Book 24: New Experiences is the final journey highlighted in this award-winning e-book series from IEEE-USA. Thanks to an inspirational teacher, author Shelly Born realized in eighth grade how much she enjoys mathematics. However, it wasn't until she was a high-school senior that she saw how her passion for math could lead to a career in engineering.

During a dinner-table conversation with family friends about what she would study in college, one of them commented that Born's interest in math, science and problem solving were a natural fit with engineering.

"They had engineers in their family, but I had never known one," she says. "In fact, I wasn't exactly sure what an engineer did. However, it sounded like the most challenging degree I could set my sights on."

The story of how this IEEE Senior Member attained her engineering degree, developed a rewarding career, and achieved both professional and personal fulfillment, is the subject of the 24th and final volume in the award-winning IEEE-USA Women in Engineering (WIE) E-Book series.



Critical Thinking Skills for Engineers—Book 5: On Problem-Solving is the final book in this acclaimed IEEE-USA E-Book series, by author Sridhar Ramanathan.

Noted engineer and business executive Dinish Paliwal once remarked, "Problem solving is essential to engineering. Engineers are constantly on the lookout for a better way to do things."

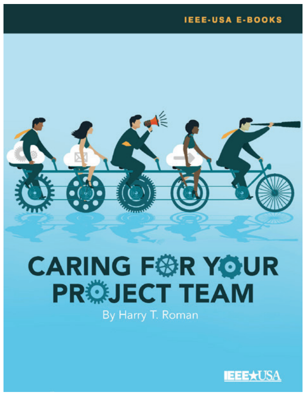
And in this fifth – and final – volume of his valuable e-book series, Ramanathan provides 10 proven strategies that offer a better way to do just that. His discussion of each method should motivate even the most jaded technical professionals to explore and manage engineering challenges with a fresh perspective.

Ramanathan, who is managing director and co-founder of Aventi Group, a high-tech product-marketing group in San Francisco, firmly believes that critical thinking is vital for engineers and other technical professionals. "It enables you to help deliver the most effective and potentially novel breakthrough solutions you can," he says.

The author packs this final volume with many helpful ideas to boost one's problem-solving abilities using these methods:

- Problem statement
- Root cause analysis
- Abstraction
- Analogy
- Brainstorming
- Trial and error
- Hypothesis testing
- Divide and conquer
- Lateral thinking
- Reduction

The latest new Audiobooks from IEEE-USA:



Caring for Your Project Team, by author Harry T. Roman, offers advice for project team leaders.

"Individual commitment to a group effort – that's what makes a team work, a company work, a society work, a civilization work," the great football coach Vince Lombardi once observed.

To that, veteran engineer and educator Roman adds, "And nothing builds professional skills better and faster than leading project teams."

Moreover, if you have any doubts about that, one glimpse at Roman's résumé will confirm he knows what he's talking about. He spent much of his 36-year career doing that in R&D at PSE&G, New Jersey's largest utility company. Now, to encourage other professionals, and lend them a hand with leading successful teams, IEEE-USA is offering the audiobook version of Caring for Your Project Team. It's a valuable resource for anyone who may be asked to lead a project team – whether they are brand new at it or experienced at leading a team.

The author emphasizes that project teams vary, according to their specific assignment. In Roman's case, many of the teams he led typically involved large-issue concepts and projects. They included developing an advanced technique for power-system load-flow analysis, or using robots in nuclear power plants, and other utility operations. Moreover, his teams usually entailed three- to five-year member commitments, large budgets, and often included vendors and outside consultants.

Nevertheless, he lists a basic set of activities that he says characterize the movement and evolution of a team: Pulling toward a common goal, doing something important for the company, growing members' skills and professional toolbox, learning how to lead teams themselves, and sharing a feeling of accomplishment. In addition, Roman devotes several chapters of his audiobook to key areas where team leaders need to devote special attention in managing their groups.

In the other new IEEE-USA Audiobook, ***Boosting Team Creativity,*** author Harry T. Roman once again comes to the fore, to help managers or team leaders seeking innovative strategies to help their organizations succeed.

In ***Boosting Team Creativity,*** Roman discusses that when people come together to use their imaginations and diverse perspectives, creativity becomes "nothing less than rocket fuel." In fact, he believes that creativity is not only vital to the health and vigor of a project team, but can also "change a business, give it new perspective, re-envision it, and perhaps, even disrupt it completely."

The author presents a persuasive case for encouraging employees' creativity, which he says can help a company to zoom past the competition and gain strategic advantages. Roman presents a multitude of approaches to encourage employees' abilities to generate ideas for problem solving. He also provides helpful advice on how individuals can regain creativity lost to email, and other technological distractions.

Students, Members: Download all of IEEE-USA's new e-books and audiobooks for your resource and listening libraries today for free – all great tools and references for your career!

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Georgia C. Stelluto is IEEE-USA's Publishing Manager; Manager/Editor of IEEE-USA E-BOOKS; InFocus Department Editor for IEEE-USA InSight; and Co-Editor of the IEEE-USA Conference Brief.

IEEE-Eta Kappa Nu Launches IEEE-HKN Career Center

IEEE-Eta Kappa Nu

HKN

IEEE-Eta Kappa Nu is proud to announce its new IEEE-HKN Career Center–the premier resource to connect career opportunities with highly qualified engineering talent.

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MANAGE YOUR CAREER:

- Search and apply to more Engineering jobs than in any other job bank.
- Upload your anonymous resume and allow employers to contact you through IEEE-HKN Career Center's messaging system.
- Set up Job Alerts specifying your skills, interests, and preferred location(s) to receive email notifications when a job is posted that matches your criteria.
- Access career resources and job searching tips and tools.
- Have your resume critiqued by a resume-writing expert.

RECRUIT FOR OPEN POSITIONS:

- Post your job in front of the most qualified group of Engineering talent in the industry.
- Promote your jobs directly to candidates via the exclusive Job Flash email.
- Search the anonymous resume database to find qualified candidates.
- Manage your posted jobs and applicant activity easily on this user-friendly site.

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