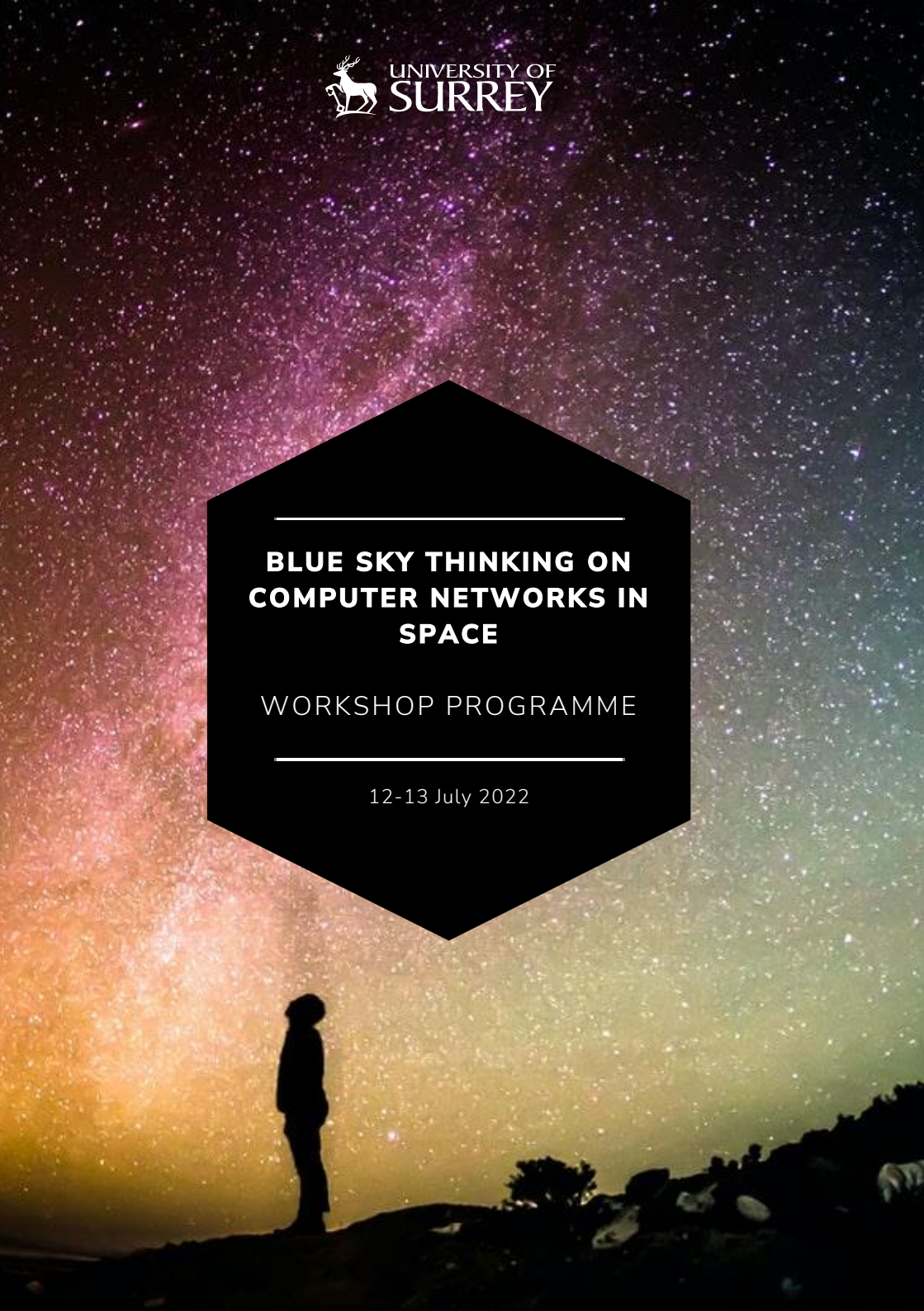

BLUE SKY THINKING ON COMPUTER NETWORKS IN SPACE

WORKSHOP PROGRAMME

12-13 July 2022

OUR SPONSOR

IAS Institute of Advanced Studies

The Institute of Advanced Studies (IAS) at the University of Surrey sponsors workshops and Fellowships at the 'cutting edge' of science, engineering, social science and the humanities. Through this scheme the Institute fosters interdisciplinary collaborations and encourages a flow of international scholars to visit, enjoy their stay at Surrey and leave behind excellent ideas and innovations.

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Workshop Organisers:

Prof Nishanth Sastry, University of Surrey
Prof Jonathan Black, University of Surrey / Virginia Tech
Dr Mohammed Kassem, University of Surrey

Administrative support:

Philip Morriss, University of Surrey
Vicki Blamey, IAS, University of Surrey

INTRODUCTION

Constellations of thousands of satellites will envelop the earth to provide new kind of high-throughput and low-latency connectivity. These new mega-constellations such as Elon Musk's Starlink, Amazon's Kuiper, or OneWeb rely on large numbers of Low Earth Orbit (LEO) to cut down the latency from 250 – 300 milliseconds (in the case of geostationary satellites) to a few tens of milliseconds, enabling entirely new classes of exciting applications such as low-latency algorithmic trading across distances, or providing high throughput connectivity to difficult-to-reach locations such as oil rigs.

However, the problem at hand -- providing reliable high-bandwidth connectivity between fast-moving objects in space -- is extremely complex, and many aspects are as yet unresolved. These developments, especially the need to create a network of unprecedented numbers of satellites when they are dynamically moving in their orbits, call for new network protocol and architecture research. This has led to a flurry of interest from computer networking researchers across the world ever since the first Starlink satellite launched in 2018.

However, there is an acute need for this line of work to consider and be informed by the realities and difficulties of satellite engineering and space systems engineering – for example, the networks need to work as the satellites pass by at extremely high speeds, and space radiation can randomly flip bits on ordinary electrical systems, calling for radiation hardening.

This workshop brings together academia from both the satellite engineering and computer networking communities and industry over two days to provide each community exposure to state-of-the-art knowledge, showcase novel transatlantic testbeds, explore problems, and create a common research agenda.

This workshop will also host funding opportunities panel discussion with panelists from the National Science Foundation (NSF), US, the Engineering and Physical Sciences Research Council (EPSRC), UK, and others to have a two-way discussion about what funding options currently exist, as well as new research questions that the researchers would want to bring to the attention of the funders.

PROGRAMME

DAY 1 – TUESDAY 12TH JULY

39BB02, Alan Turing Building

(BST)

14.00 – 14.15	Introduction - Prof Nishanth Sastry and Prof Jon Black
14.15 – 14.45	Internet standards for the Next Generation of Satellite Systems – Prof Gorry Fairhurst, University of Aberdeen
14.45 – 15.15	Towards measuring Low-Earth Orbit network performance – Debopam Bhattacherjee, Microsoft Research, Bangalore
15.15 – 15.45	Break
15.45 – 16.45	SpaceNet Testbed Demonstrations
16.45 – 17.15	Validating and exploiting the networks of the future – Andy Marr and Jon Earl, CGI
17.15 – 17.45	Vodafone and the AST Space Mobile – Connecting the unconnected - Rowan Chesmer, Vodafone
17.45 – 18.15	Congestion in Space: Managing Traffic across Megaconstellations - Prof Mark Handley, UCL
18.15 –	Drinks reception

DAY 2 – WEDNESDAY 13TH JULY

39BB02, Alan Turing Building

(BST)

11.00 – 12.00	Networking
12.00 – 13.00	Lunch
13.00 – 13.30	Making space seamless from orbit to ground – Prof Malcolm Macdonald, University of Strathclyde
13.30 – 14.00	LunaNet: a Flexible and Extensible Lunar Exploration Communications and Navigation Infrastructure and the Inclusion of SmallSat Platforms - Dave Israel, NASA
14.00 – 14.30	Break
14.30 – 15.30	Lightning talks of work at Surrey and Virginia Tech: Chris Bridges (Surrey Space Centre) 'Space Observation & Sustainability Zhili Sun (Surrey 5G Innovation Centre) 'Update on the IEEE Satellite 5G and beyond Working Group' Mohamed Kassem (Surrey Distributed and Networked Systems Group) 'A Browser-side View of Starlink Connectivity Sam Kenyon (Space@VT) 'Network Testbed for Small Satellites (NeTSat) – Virginia Tech Capabilities'
15.30 – 16.00	Space Robotics Applications and Research Needs with focus on Networking and Distributed Data Collection - Prof Ella Atkins, Virginia Tech
16.00 – 17.00	Panel: Research Funds Deep Medhi - NSF Laura McDonnell – EPSRC UKRI Tom Kirkham - Innovate UK Fabrizio De Paolis, ESA - European Space Agency
17.00 – 17.10	Closing comments - Prof Nishanth Sastry and Prof Jon Black

ABSTRACTS AND PARTICIPANTS

TUESDAY, 12TH JULY

Internet Standards for the Next Generation of Satellite Systems

Prof Gorry Fairhurst, University of Aberdeen

Internet and Space Standards reflect the needs of different layers of communication. They have typically addressed different goals, and are set by different standards development organisations. This talk will look at what is needed to support a satellite Internet service, and how the requirements have changed with the introduction of high capacity satellite systems and Internet developments, such as pervasive encryption of transport-layer protocol information. The talk will examine what is needed for next generation satellite Internet services and some of the challenges that lie ahead in setting new standards.

Biography

Prof Gorry Fairhurst is an Internet Engineer, and has a Chair in the School of Engineering at the University of Aberdeen, Scotland. Research built from initial work on Internet over satellite in 1999, now has developed a focus on Internet Engineering. His active research currently focuses on Internet Engineering (congestion-control, path interactions, QoS, multimedia transport, TCP, QUIC, Internet capacity sharing, low-latency, and encrypted transport protocols). This includes activities in Internet Measurement and Protocol Design (large scale measurement of Internet path characteristics and impairments) and Satellite Internet (IP over satellite, and higher layer protocols for broadband satellite access). He contributes to standards development, including 10 specifications to the Digital Video Broadcast and ETSI and is an active participant in the Internet Engineering Task Force (IETF), where he contributes to the Internet and Transport Areas. He has authored 30 RFCs, with over 200 citations within the RFC series. He provides technical oversight and leadership as a chair of the IETF Transport Area Working Group.

Towards measuring Low-Earth Orbit network performance

Dr Debopam Bhattacherjee, Microsoft Research, Bangalore

Upstart space companies are building massive constellations of low-flying satellites to provide Internet service. These developments comprise “one giant leap” in Internet infrastructure, promising global coverage and lower latency. However, fully exploiting the potential of such satellite constellations requires tackling their inherent challenges: thousands of low-Earth orbit (LEO) satellites travel at high velocities relative to each other, and to terrestrial ground stations. The resulting highly dynamic connectivity is at odds with the Internet’s design, which assumes a largely static core infrastructure. Virtually every aspect of Internet design — physical interconnection, routing, congestion control, and application behavior — will need substantial rethinking to integrate this new building block.

In this talk, I will present Hypatia, a framework for simulating and visualizing LEO networks that we built to enable broader research in this area. Using publicly available design details for the upcoming networks to drive our framework, we characterize the expected behavior of these networks, including latency and link utilization fluctuations over time, and the implications of these variations for congestion control and routing.

I will conclude by discussing the benefits of building a globally spanning measurement infrastructure for LEO broadband networks, much like PlanetLab and MeasurementLab for the Internet today. The envisioned testbed will empower the research community to study the various temporal and spatial aspects of these highly dynamic “new space” networks.

Biography

Debopam recently joined Microsoft Research - India as a Senior Researcher after receiving his PhD in computer networks from ETH Zurich. His research focuses on “new space” satellite networks, low latency terrestrial networks, and Internet architecture. His research work has received multiple awards in the past -- IRTF’s Applied Networking Research Prize 2020, a Best Paper Award at IMC 2020, and a best dataset award at PAM 2020. His work on designing speed-of-light ISP networks, published at NSDI this year, and some of his past work has received significant attention from the digital media. Debopam earned his masters degree from KTH Royal Institute of Technology. He earned his bachelors degree in computer science from Jadavpur University. For further details, please refer to his web page.

Validating and exploiting the networks of the future

Andy Marr and Jon Earl, CGI

CGI have been exploring the use cases and technological capability enabled through the combination of satellite communications and 5G through our investment in a mixed Future Networks lab in our facility in Leatherhead and our co-created ESA 5G/6G Hub at ECSAT. In this talk we will explore the vision, capability and roadmap for these facilities and discuss the lessons we have learned so far.

Biographies

Andy Marr leads CGI's 5G programmes in its Space division. His team have delivered the European Space Agency's 5G/6G Hub, showcasing how space can enable future generations of telecommunications and connected applications, CGI's Carnot-Sat hybrid networks planning tool, and their hybrid networks Management and Orchestration toolset, underpinned by CGI's 5G Accelerator facility in Leatherhead. Andy has 15 years' experience working in the Space industry, delivering critical solutions for customers including OneWeb, SES, Inmarsat and AST SpaceMobile.

Jon Earl is a senior solution architect with over 20 years' experience in CGI's Space business, designing and delivering distributed systems across our Navigation, Earth Observation and Satellite Communications domains. Jon is the solution architect for the ESA 5G/6G Hub.

Vodafone and AST Space Mobile - Connecting the unconnected

Rowan Chesmer, Vodafone

Vodafone aims to close the digital divide across the globe with this exciting new solution which will allow millions of people and devices to have connections in rural parts of the world that was previously never possible. It will achieve this by enabling your current unmodified smart phone to connect directly to a satellite to provide 4G and 5G connectivity.

Biography

Rowan Chesmer is the technical lead for future looking Non-Terrestrial networks in Vodafone's R&D department. Responsible for trialling and developing cutting edge satellite technologies with the aim of ever improving global connectivity for people and devices. Rowan has been with Vodafone for 5 years, before which he worked on innovative solutions for improving logistics and manufacturing efficacies in a couple of different sectors and completed his masters in electronic engineering at Durham University.

Congestion in Space: Managing Traffic across Megaconstellations
Prof Mark Handley, UCL

Large constellations such as Starlink that use high-speed inter-satellite links have the potential to provide wide-area networks that beat the best optical fibre networks for latency. Making good on this promise is not simple though - meshy networks performing shortest-path routing have an inherent tendency to inadvertently concentrate traffic into hot spots. If queues of packets are allowed to build in satellites, the potential for low-latency service will be lost. This problem is shared by well-connected terrestrial networks where centralized traffic engineering schemes have been used in recent years to route traffic aggregates over multiple paths with the goal of avoiding congestion. Such schemes require reasonably predictable traffic and good knowledge of this demand. Given such information they can take tens of seconds to calculate a routing solution and deploy it. The best path through a network such as Starlink might commonly change every ten seconds or less, with the nth best path changing even more frequently. Real-time multipath routing and resource control necessary to run such networks at moderately high utilization is therefore a huge challenge. I will discuss the problem space, and talk about possible directions to address this challenge.

Biography

Mark Handley joined the Computer Science department at UCL as Professor of Networked Systems in 2003, receiving a Royal Society-Wolfson Research Merit Award. From 2003-2010 he led the Networks Research Group, which has a long history dating back to 1973 when UCL became the first site outside the United States to join the ARPAnet, which was the precursor to today's Internet. Prior to joining UCL, Professor Handley was based at the International Computer Science Institute in Berkeley, California, where he co-founded the AT&T Center for Internet Research at ICSI (ACIRI). Professor Handley has been very active in the area of Internet Standards, and has served on the Internet Architecture Board, which oversees much of the Internet standardisation process. He is the author of 33 Internet standards documents (RFCs), including the Session Initiation Protocol (SIP), which is the principal way telephony signalling is performed in Internet-based telephone networks. Recently he has been standardizing multipath extensions to TCP.

WEDNESDAY, 13TH JULY

Making space seamless from orbit to ground
Prof Malcolm Macdonald, University of Strathclyde

Space has become more accessible than ever before and has the potential to transform life on Earth. But, only if fundamentally new ways of perceiving, designing, and operating these systems are established. The next space age will necessitate new methods and insights to operate spacecraft as networked systems rather than isolated, individual objects, driving a shift from individual spacecraft to large networks of cooperative, self-organising satellites. This talk will review the work of the Applied Space Technology Laboratory, connecting starlings to human brains, and onwards to the spread of contagion: we're developing insights into network systems across the natural sciences to engineer vastly more connected, efficient, and sustainable space systems

Biography

Malcolm is the Director of the Applied Space Technology Laboratory at University of Strathclyde, and a Visiting Professor at the Centre for Space Research at University College Dublin.

He is also a Director of Weather Stream, a US-based weather analytics company deploying a proprietary constellation of spacecraft, and a member of the Industry Advisory Board of Seraphim Space, the world's leading specialist investor in SpaceTech. He was a non-executive member of the UK Space Agency Steering Board from 2017 – 2020, and is currently Vice-Chair of the Agency's Space Technology Advisory Committee. His work aims to enable and develop new space-derived services through advancing a range of new technologies. To enable this his research has an end-to-end focus on the development and application of systems, challenging conventional ideas and working at the interface between disciplines. His work develops concepts in, and applications of space technology by developing research into astrodynamics, networked systems, swarming, and distributed and collaborative systems to advance new concepts in the exploration and exploitation of space. Based on citation metrics analysis, I'm recognised as being in the top 2%, globally, of engineering researchers [doi:10.17632/btchxktzyw.3].

LunaNet: a Flexible and Extensible Lunar Exploration Communications and Navigation Infrastructure and the Inclusion of SmallSat Platforms

Dave Israel, NASA

As NASA establishes a sustained presence on the Moon and ventures further into the solar system, the need for a robust interplanetary communications and navigation architecture increases. LunaNet, an extensible and scalable lunar communications and navigation architecture, is being developed to answer this growing need. The LunaNet architecture will provide users with three services: networking services, positioning, navigation and timing services, and science utilization services. With LunaNet in place, users will experience an operational environment similar to that experienced by users on Earth. The agency's plan for solar system exploration necessitates both government and commercial participation, and the LunaNet architecture supports this goal as well, encouraging global participation from commercial and international partners, other government agencies, academia, and federally funded research development centers. In this talk, I will talk about a high-level description of the LunaNet architecture, discuss how SmallSat platforms and technologies may provide critical capabilities, and define the role that SmallSats can play within the architecture

Biography

Dave Israel is the Exploration and Space Communications Projects Division Architect and the Principal Investigator for the Laser Communications Relay Demonstration (LCRD) at the NASA Goddard Space Flight Center. He has been working on various aspects of space communications systems, since joining NASA in 1989. He led the study team that produced the LunaNet architecture concept, building upon previous work performed both within NASA and externally. He has also led the development of various operational systems and has been the principal investigator for multiple communications technology activities concerning advanced space communications concepts and networking protocols, including the LPT CANDOS experiment on STS-107 and Disruption Tolerant Network demonstrations on the Lunar Laser Communications Demonstration.

Space Robotics Applications and Research Needs with focus on Networking and Distributed Data Collection

Prof Ella Atkins, Virginia Tech

Space-based communication networks have enabled live worldwide broadcasts for decades. More recent LEO constellations reduce delay to offer public networking services competitive with ground-based options. Space assets for science and surveillance are also proliferating, and ambitious manned missions to the moon and beyond are being designed. This talk will describe how space assets can coordinate with aerial and ground assets to provide unprecedented levels of coordinated data collection. Space robot systems will be essential to support proximity operations needed to repair, augment, deorbit, or otherwise support high-value space assets and human spaceflight missions.Key space robotics research, deployment, and operational challenges will be presented along with a summary of promising solutions

Biography

Prof Ella Atkins has been appointed head of the Kevin T. Crofton Department of Aerospace and Ocean Engineering in the College of Engineering at Virginia Tech, effective Aug. 1. She currently holds the position of professor of aerospace engineering at the University of Michigan, where she directs the Autonomous Aerospace Systems Lab and until 2020 served as associate director of the university's Robotics Institute. Recently she spent a year as a technical fellow at Collins Aerospace, gaining industry research and development experience while also offering expertise in aerospace artificial intelligence and machine learning. As an academic researcher, Prof Atkins has focused on perception, decision-making, and control algorithms to improve performance and safety of unmanned aircraft systems and advanced air mobility operations. With autonomous systems and artificial intelligence increasingly applied to both aeronautics and space engineering applications, she envisions a wealth of new opportunities to inform and exploit cloud-based data, real-time perception, and explainable data structures to support optimal decision-making with long-duration mission autonomy and for collaborative human-machine systems.

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