



Comcast Innovation Fund

2016 Annual Report

Summary of the Fund's Operations for the 2016 Operating Year

Comcast Innovation Fund At a Glance: 2016 Executive Summary

Background

Comcast created the Comcast Innovation Fund to identify and support important research that has the potential to advance broadband, the internet and the global open-source community. The fund was established as a resource for researchers working on smaller and mid-sized technology projects that may not qualify for larger national grant programs.

Grants range from \$3,000 for smaller projects, up to more than \$100,000 for medium-term research efforts. A cross-functional team of technology and business leaders within Comcast reviews grant applications and directs funding where it is most needed, and can have the greatest impact. The fund was backed by a million-dollar commitment from several groups within Comcast in 2013, and that level has been renewed for 2017.

Comcast recently concluded the fourth full year of the grant program, and issued 25 grants to applicants in six countries.

Objectives and Key Criteria

The fund was created to advance the internet and open-source technology, so we look for research projects that move technology forward by tackling difficult problems or pioneering new approaches. In 2016, particular weight was given to projects that:

- Advance privacy and cybersecurity
- Create or advance important open-source projects
- Advance the development and adoption of emerging open internet standards
- Improve the accessibility, stability, security, growth, and impact of the internet

- Improve the internet experience through Quality of Experience (QoE) and other internet measurement-related efforts
- Address performance bottlenecks, security issues, and other issues of interest in home networks
- Advance the Internet of Things and machine-to-machine communication

Grant Categories

The fund offers two primary types of grants, though we increasingly see some grant applicants combining these types into a unified grant.

- **Research Grants** - These unrestricted grants are given to support researchers at colleges, universities, and other organizations. They are geared toward supporting research in a range of fields relevant to the internet and online communication. Research Grants can be either general or targeted. A general research grant provides an unrestricted award of funds to support researchers, usually at colleges and universities. These grants are focused on supporting excellent technical research in a wide variety of fields that are relevant to the broadband industry and/or to Comcast specifically. In contrast, a targeted research grant is more narrowly tailored to more specific issues. In either case, applicants are encouraged to consider grants that may have a cooperative focus, whereby researchers can be matched with a Comcast engineering liaison who will be involved with the research.

- **Open Source Development Grants** -

Comcast is an active and engaged participant in the global open source community. These grants are intended to support the creation and advancement of important open source projects, including those that may not have immediate business value, but which carry the potential for important technological development. Open Source Development Grants are intended to fund new or continued development of open source software in areas of interest to Comcast or of benefit to the internet and broadband industries. This can fund a range of development, from adding specific features to an existing open source project, to general support of an open source project in which we are interested.

2016 Highlights

Projects supported by fund in 2016 included:

- **The Domain Name System Operations, Analysis and Research Consortium (DNS-OARC)** that can help technologists better respond to distributed denial of service (DDOS) attacks (page 6)
- **University of Southern California (USC)** research that focuses on identifying and breaking down the barriers women-owned businesses experience in accessing global supply chains (page 9)
- **Grier Forensics'** open source plugin designed to make it easier for ordinary Internet users to send and receive secure, encrypted e-mail (page 7)

Grants Made by Country in 2016

Australia	2
Brazil	1
Czech Republic	1
Greece	1
Serbia	1
USA	19

Looking Forward

The grant process for the 2017 funding year has begun, and Comcast continuously reviews applications to identify new, worthy projects. For more details, or to direct someone to apply, visit <http://innovationfund.comcast.com>.

Comcast Innovation Fund Annual Report 2016

Individual Grant Insights

Application Developers Appliance

Grant Type: Research and Open Source Development

TV Developer Research and Open Source Project (2 Grants Awarded)

This project aims to encourage more developers to work on TV app projects, including by creating a specific open source project to which they can contribute. The first step is to conduct a first-of-its-kind, in-depth research project to gauge attitudes and opinions of developers towards developing apps for TV in order to understand existing attitudes towards TV app projects, including why developers choose to pursue them and why they choose otherwise. Survey findings will help to generate and refine ideas for an open source project. A subsequent step is to choose one open source TV project with which to move forward. A report on attitudes towards TV app development, covering the current developer landscape, including top challenges and opportunities as well as what the near-future holds for TV apps, will be one of the outputs of the project. In addition, a report on TV development as a career path will be created in tandem, to explore the professional opportunities of developing for TV, including official recommendations on how to encourage the next generation of developers to pursue TV projects.

Status: In Progress

Art & Alchemy

Grant Type: Open Source Development

Open Source Virtual Reality Integration

This project focuses on open source integrations of diverse hardware sensors and displays permitting virtual reality (VR) systems to have an awareness of the user and their surroundings in physical space. The project also enhances user interaction and input with VR/AR systems. The project explores multiple different technologies, but with enough similarities in integration needs and usage that they will benefit from being executed simultaneously. The open source platform allows discovery, configuration and operation of VR/AR devices and peripherals in a manner that is platform and device

agnostic. The output of this project helps to address the challenges the VR/AR industry is facing such as hardware fragmentation. It will also prepare for possible follow-on work involving gesture tracking devices that may allow lower options in integration than is typically enabled by VR systems' primary APIs.

Status: In Progress

Asia Pacific Network Information Centre (APNIC)

Grant Type: Research

IPv6 Measurement & Analysis

The objective of this program is to measure aspects of the performance of the internet by using measurement from the outside inward. The research does not measure the network from the interior of the network or from content providers, but rather measures the network as the end user experiences the internet. The major objective is to understand the extent to which end users can take advantage of content offered from servers that are capable of passing IPv6 jumbograms into the network. The experiment is intended to measure the extent to which the network is capable of supporting large packets, and the extent to which the ICMP MTU notification messages are being delivered if this support is not available on a network path.

Status: In Progress

Center for Applied Internet Data Analysis

Grant Type: Research and Open Source Development

Quality of Experience (QoE) Measurement

CAIDA is developing techniques to measure congestion at inter-domain interconnections on the internet. As part of that ongoing project, CAIDA will research how to move toward measurement of user Quality of Experience (QoE), analyze how QoE depends on network-level performance metrics, and correlate latency-based evidence of a highly utilized interconnects with broadband speed and QoE measurements. In addition, the project will build on Comcast's plans to release an open source speed testing application to provide more accurate measurements of a user's broadband access speed

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Individual Grant Insights (cont.)

and also to release a distributed measurement infrastructure that may enable uniquely large-scale QoE measurements. The project will also participate in enhancing this open source software, analyzing resulting data, and will correlate measurements from this open source software with data we are currently collecting as part of CAIDA's NSF-sponsored effort to measure interdomain congestion.

Status: In Progress

Clarkson University

Grant Type: Research

Efficient Aggregation, Update Handling and Equivalence Verification on IPv6 Forwarding Tables

The number of devices and users connecting to the internet continues to grow at a fast pace and increasingly relies upon IPv6 addresses. As a side effect, the size of routing tables in core internet routers is growing fast and threatens to exceed a size that many such routers can handle, which has the potential to cause router outages and service disruptions. To overcome or mitigate these problems, aggregating the Forwarding Information Base (FIB) may be a potentially effective solution and would not require architecture or hardware changes. The solution to be researched should therefore be relatively easy to deploy because it is a software solution, local to single routers and does not require coordination between routers in a network or between different networks. The project is to design and develop new efficient aggregation algorithms that are able to maximally aggregate IPv6 FIB entries and incrementally handle route updates. The project will also develop a novel verification algorithm that can efficiently test the forwarding equivalence between any two IPv6 forwarding tables.

Status: In Progress

Columbia University & Universidade Federal De Minas Gerais (UMFG), Brasil Fundação de Desenvolvimento da Pesquisa (FUNDEP)

Grant Type: General Research

Unlocking the Potential of the RIPE Atlas Platform

Researchers and operators have traditionally lacked a rich view of internet routing, with existing testbeds

lacking diversity, openness, and widespread coverage. The RIPE Atlas probe platform provides unprecedented visibility, with vantage points in thousands of networks and has already been the measurement basis for a number of research studies and operational uses. Despite its promise, RIPE Atlas is limited in a number of ways that restrict the types of studies for which it is suitable. This project will attempt to address some of these limitations. The widespread deployment of RIPE Atlas probes has been an enormous boon to the internet measurement community, and this project will undertake to increase its value to researchers and operators, thereby magnifying its impact.

Status: In Progress

CZ.NIC

Grant Type: Open Source Development

Open Source Home Network Security System with Focus on IoT and Parental Control

This project aims to implement an easy to use but powerful tool for a home or small business to monitor their network in open source home gateway devices. This system will be complemented by a parental control function that could enable a user to set rules of internet access for different devices in the network. One of the important features the project plans to include is a name-based firewall, which is a combination of a firewall with a passive DNS probe. This concept allows for much better and more natural control of firewall settings than an IP address-based one. The output will be software that will run on a common Linux-based system and more specifically on devices running OpenWrt. It will be released as open source and offered to users of the Turris Omnia router as an additional service. The publication of this software will be communicated in media and topical conferences (RIPE, NANOG, etc.).

Status: In Progress

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Individual Grant Insights (cont.)

Domain Name System Operations, Analysis and Research Consortium (DNS-OARC)

Grant Type: Open Source Development

DNS Replay Tool, “drool”¹

This project will develop a tool that can replay Domain Name System (DNS) traffic from packet capture (PCAP) files and send it to a specified server with the option to manipulate the timing between packets, as well as loop packets infinitely or for a set number of iterations. This tool will need to be able to produce a minimum of 200,000 UDP packets per second and 10,000 TCP sessions per second on common hardware. The purpose is to simulate Distributed Denial of Service (DDoS) attacks on the DNS and measure normal DNS querying. For example, the tool could enable you to take a snapshot of a DDoS and be able to replay it later to test if new code or hardening techniques are useful, safe and effective. Another example is the ability to replay a packet stream for a bug that is sequence and/or release a BSD-licensed software tool for UNIX systems along with documentation.

Status: Complete

Drexel Glass-to-Glass Internet Ecosystem (GGIE)

Grant Type: Research and Open Source Development

Evolving Video Content Naming, Addressing, and Network Delivery

Video creation and delivery is the top use of internet bandwidth and presents a scale challenge for the internet. Building on the successful deployment of IPv6 by network operators like Comcast, GGIE extends IPv6 and digital video packaging to enable both to work smarter together. The project focuses on video content naming and addressing schemes, with a focus on extending these schemes to support direct IPv6 addressing of content, which in turn will permit faster, better nearest cache selection, and will enable the network infrastructure to carry video more efficiently. The project made significant progress in 2016, with a working demonstration version of the system shown in public, and four internet drafts submitted to the IETF.

Status: In Progress

Georgia Institute of Technology (Georgia Tech)

Grant Type: Open Source Development

Netrisk Internet of Things Accounting (IOTA) Project

Netrisk is a startup out of Georgia Tech that is focused on internet-based analysis of threats, malware, and abuse at the network edge. Researchers at Netrisk and Georgia Tech are focused on how to use DNS and network information to build inventories of Internet of Things (IoT) devices on local networks, such as in-home networks. The project uses machine-learning techniques to inventory IoT devices on local networks. The IOTA system uses features only drawn from DNS and/or Layer-2 to passively identify unknown devices. IOTA's benefits are that (1) it preserves existing investment in DNS intelligence systems, and (2) demonstrates the potential for passive, non-DPI, and privacy-aware techniques to help manage infections in IoT networks. Utilizing data from a large recursive DNS server, the researchers at Netrisk were able to develop a research prototype system that is able to both cluster similar domain names that summarize the traffic of a particular class of IoT devices, and come up with the necessary statistical features to model such behavior using “DNS Grammars”. In an operational sense, the clustering process is able to automatically identify new clusters of domain names that are likely to be used (at the time window) by known or unknown IoT devices. The “DNS grammar” component of the system is able to model such traffic, and effectively provide to the operator the ability to in-line and, in a very lightweight manner, “mark” end points that “talk” various IoT dialects — again, solely from the point of their DNS communications and their temporal patterns.

Status: Complete

¹<https://medium.com/@dnsoarc/drool-release-1-0-0-beta-2-a-dns-replay-tool-c3f380d3066c>

Individual Grant Insights (cont.)

Grier Forensics

Grant Type: Open Source Development

Trusted Friends Secure Email Project

This project is focused on how to make secure, encrypted email easier for the average person to use by integrating encrypted email into common email clients and webmail. The objective of the first phase of the project was to build a DANE-based plugin for the popular Thunderbird email client as a proof-of-concept that could then be applied to other clients and webmail systems if successful.

Status: Complete

Internet Society, Serbia Chapter

Grant Type: Open Source Development

IoT & Wearables Hackathon

This grant provided support for the DesCon 2016 IoT Hackathon, which took place over two days in August 2016. This exciting hackathon brought together over 60 technologists, hackers, makers, designers, computer enthusiasts, and artists who combined their skills to create fashionable wearables and other IoT devices that can be used in daily life to alert users to activities in their surrounding environment. Attendees participated in hands-on workshops focusing on the development of hardware and software, as well as talks on Digital Compression Loss, Ethereum mining, and BlockChain. Guest speakers included Matthew Jackson from Doctor2Go (New Zealand) and Kristina Nikolic from Strawberry Tree (Serbia), who both shared insights into how each company developed into the successful IoT startups they are today. Participants designed and assembled hardware using Arduino Nano computers and sensors, wrote code to create fashionable IoT wearables, and learned hands-on tactics for how to build IoT devices.

Status: Complete

Massachusetts Institute of Technology (MIT)

Grant Type: Research and Open Source Development

Advancing Open Source Speed Testing, Data Analysis and Related Institutional Questions

This project involves research work within the larger community emerging around the efforts to build open source broadband measurement systems. On the technical side, the project will work on code

contributions to the open source testing tools as well as the analytic systems build around the gathered measurements. While the project foresees significant technical contributions, it also explores institutional questions such as (1) how will the data be shared and archived, (2) what policies will govern access, (3) at what granularity will data be available to different stakeholders, (4) what privacy considerations arise and how will they be addressed, and (5) who or what process controls how the system, both technically and institutionally, evolves over time?

Status: In Progress

Murdoch University

Grant Type: Open Source Development

Adding Covert Channel Detection to an Open Source Intrusion Detection System

This grant attempts to develop software for Intrusion Detection Systems that can detect “covert channels”. These covert channels can be used by hackers, criminals, terrorists, rogue insiders, and others to hide communications by embedding a covert communication inside a seemingly normal one (such as a graphic file or movie). These covert channels pose a tangible security risk to enterprise networks, ISPs, and others.

Status: In Progress

Princeton University, Center for Information Technology Policy (CITP)

Grant Type: Research

Interconnection Measurement Project (IMP)

The IMP created a collaboration between Princeton, CableLabs, and six ISPs to develop an ongoing cross-ISP broadband interconnection measurement research study. The continued goal of the study is to publicly and transparently provide factual data and rigorous technical analysis of interconnection capacity and utilization. IMP provides the most comprehensive set of technical findings on interconnection capacity and utilization ever made public. In addition, the project website provides graphs and cumulative data in a de-identified and aggregated manner that enables industry-wide conclusions to be drawn without disclosing individual participating ISP’s results and trends.

Status: In Progress

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Individual Grant Insights (cont.)

Technology Policy Institute

Grant Type: Research

Towards Rational Infrastructure Investment Policies (2 Grants Awarded)

Policy makers have discussed a significant expansion in infrastructure funding, including telecommunications infrastructure. This project will begin studying this, with special focus on telecommunications and other investments relevant for technology policy. Part of this project involves studying previous U.S., E.U., and other countries' initiatives, in order to learn from them to avoid previous mistakes. Based on analyses of existing infrastructure initiatives, the research will offer guiding principles on ways to raise funds in ways that minimize economic distortion and to distribute funds in the most cost-effective manner. The final output of the project will be a research paper. The paper will not address the question of whether such spending, or how much of it, is a productive use of resources. Instead, it will assume that the government will invest in new infrastructure, including broadband, and review the available evidence on existing subsidy programs and offer guidelines on creating objective ways to choose where to spend money. The paper will focus on broadband subsidies, but the general principles it derives should be more generally applicable. Hopefully, the paper will help policymakers charged with implementing an infrastructure subsidy program create a mechanism that chooses where to spend money in an objective fashion and spends the money in the most cost-effective manner possible.

Status: In Progress

Thinking Cat, LLC

Grant Type: Research and Open Source Development

TechArk Network Operator Measurement Activity (NOMA)

The NOMA project is acting as a neutral project platform to build and support the collaboration of network operators, defining an initial set of measurements to constitute the basic instrumentation of participating networks. A first target outcome from NOMA measurements will be to track the relative performance of IPv6 and IPv4

(for HTTP traffic) in participating networks. Based on the success of this first target, NOMA will investigate additional measurements and work to attract ISPs to participate.

Status: In Progress

University of Crete, Institute of Computer Science, Foundation for Research and Technology – Hellas (FORTH)

Grant Type: Research

Cost-benefit analysis of user satisfaction and QoE in the context of video-streaming based on empirical measurements

This research studies technical variables that affect video streaming quality of experience (QoE). This may vary with respect to user device, premise, type of service, and user profile. The research investigates (a) the causal analysis of QoE that take into consideration not only network and application measurements but also contextual, systems, and user viewing behavior/profile data, (b) the consideration of cost and benefits in collecting reliable measurements for identifying the appropriate features for user-centric QoE prediction, (c) the ability of the prediction framework to dynamically select the algorithm that exhibits the best accuracy in the classification and tune its parameters automatically depending on the input and its extensibility to incorporate new algorithms, (d) the use of unsupervised pre-training generative methods to incorporate large amounts of measurements without QoE scores.

Status: In Progress

University of Pennsylvania, Center for Technology, Innovation and Competition (CTIC)

Grant Type: Research

Innovative Approaches to Connecting the Unconnected at a Global Level

One of the central problems confronting the world is how to connect more people to the internet. This project will gather, analyze, and disseminate examples of innovative practices that have proven successful in promoting broadband deployment in a systematic way that permits evaluating their cost effectiveness. Understanding that many non-adopters do not see the benefits of using the internet, the project will examine demand-side as well as supply-side initiatives. If successful, this research will provide different types of countries with

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Individual Grant Insights (cont.)

an initial framework of options for expanding connectivity. The research will leverage the support of a broad-based multi-stakeholder group including civil society, governments, the technical community, and industry participants spanning the entire range of the internet ecosystem. The research will also be supported by a website. The project will also organize a series of panels at the 2017 Internet Governance Forum (IGF) to showcase the progress to date and also expects to organize additional events around the world to raise awareness and to showcase efforts. Comcast's Internet Essentials was featured as the only U.S. case study of how to increase broadband adoption.

Status: In Progress

University of Pennsylvania, Wharton School of Business

Grant Type: Research

Internet of the World Symposium

The "Internet of the World" represents the transformation of every form of economic activity along the same lines as the internet. This can be seen in a number of high-profile developments, including the Sharing Economy, the Internet of Things, Big Data, the Blockchain, Deep Learning, Offline-to-Online Commerce, Autonomous Vehicles, and Augmented Reality. This grant will support a symposium that will include both scholars and practitioners in an interdisciplinary manner and explore possible new business models, new strategic threats or opportunities, new technical challenges, and new legal questions. Output may be published in The Journal of Information Policy and may produce actionable ideas for the new U.S. Presidential Administration.

Status: In Progress

University of Southern California

Grant Type: General Research

Women-Owned Small to Medium Size Enterprises (SMEs) in Developing Countries Entering the Value Chains of Major Global Firms

Studies demonstrate that when women are working, they help each other, their families, and their communities. While women-owned SMEs can supply the world's major multinationals in every sector, according to WEConnect International, a corporate-led non-profit that certifies women-owned

businesses around the world, women-owned businesses earn less than 1% of the money spent on vendors by large corporations and governments worldwide. This research evaluates the interaction between women-owned SMEs in selected developing countries and the existing institutional barriers and opportunities they face in order for major firms to source directly from them for global consumption. It will examine what these women require to supply major firms, how such buyer/seller connections and relationships are formed, how their performance and value are measured, and how their economic activity manifests into the development of their families, communities, and society. The output of this research will include a doctoral dissertation at the USC Annenberg School of Communication and a book and/or articles, all backed by empirical research that should raise questions for academic researchers and also be of significant value to a business audience. The researcher will also present to business and academic audiences in international forums concerned about corporate citizenship and the next generation of women's economic empowerment.

Status: In Progress

U.S. Telecommunications Training Institute (USTTI)

Grant Type: Research

USTTI Cybersecurity and ICT Policy Training Program

This training program focuses on the cooperative roles of government and industry engaged in raising awareness of cybersecurity, building cybersecurity capacity, formulating a national strategy for cybersecurity, setting up national cybersecurity incident management organizations, deterring cybercrime while fostering a national culture of cybersecurity and building strong government industry partnerships in their countries. The courses discuss major international cybersecurity efforts being conducted by the U.S. and other countries; cost-effective measures to promote the development of a culture of cybersecurity and child online protection within the context of a developing economy while focusing on the respective roles and responsibilities of internet users, internet service providers (ISPs), law enforcement and defense ministries. The courses also address the broader issue of Internet Governance and the internet

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Individual Grant Insights (cont.)

ecosystem, focusing on the implications of internet standards and policy development in the context of a global internet economy. The intended outcome for this program will be to equip developing country leaders with the skills necessary to work in a multi-stakeholder environment where they will feel confident interacting with government, civil society and industry to develop Internet policy and strategies to address the cybersecurity challenges they are facing.

Status: Complete

Villanova University

Grant Type: Research and Open Source Development

Migration of Undesirable Association Behaviors of Mobile Devices With Public WiFi Networks

A user's mobile device may frequently access public WiFi hotspots for internet service. When the user returns to their residence, the mobile device has a tendency to associate to the public WiFi network rather than the user's private home network if both are available. The association of a mobile device with the last known good network is quite appropriate in cellular networks (where this vestigial behavior originates) for connection stability reasons, but is undesirable for computer networks for many reasons and can frustrate users and result in a poor user experience (UX). This project explores several possible approaches to solve this problem, by developing and testing a variety of methods to perform frame-manipulation at the Medium Access Control (MAC) sublayer of the IEEE 802.11 protocol. After conducting the initial feasibility studies examining the above approaches, an open source hardware-software router platform will be used to implement a prototype solution. The end result of the project is a reference model, associated open source software, documentation, IEEE paper, and patents.

Status: In Progress

