SPECTRUM COLLABORATION CHALLENGE

USING AI TO UNLOCK THE TRUE POTENTIAL OF THE RF SPECTRUM

CHAMPIONSHIP EVENT
October 23, 2019 | Los Angeles, CA

DARPA

#DARPASC2
**EVENT AGENDA**

3:30 - 4:00  Introductions & The Challenge
4:00 - 5:00  Elimination Rounds
5:00 - 6:00  Final Round & Award Ceremony

**About SC2**
Spectrum scarcity is a looming threat to the future of 5G and beyond. Can artificial intelligence manage our rapidly depleting spectrum resources, while enabling faster data speeds, connecting billions of devices, and supporting a 5G future? DARPA’s Spectrum Collaboration Challenge (SC2) seeks to answer this question. Over the past three years, SC2 has challenged teams from academia, commercial, and defense communities to build wireless networks that can autonomously collaborate and reason about how to share the RF spectrum moment-to-moment. Today, these networks will go head-to-head to determine the $2M grand prize winner, and open a new era for wireless innovation.

**EVENT HOSTS**

**Paul Tilghman**
SC2 Program Manager, DARPA

Paul Tilghman is the DARPA Program Manager responsible for SC2. For the past five years, Paul has developed and led a portfolio of research programs that explore cognitive RF systems capable of delivering revolutionary wireless capabilities to the defense and commercial industries. These research efforts span intelligent and adaptive RF systems, digital signal processing, machine learning, wireless communications, and novel high performance computing architectures.

**Grant Imahara**
Host, Mythbusters and White Rabbit Project

For almost a decade, Grant Imahara was one of the hosts of Discovery Channel’s “Mythbusters.” Since his time on “Mythbusters,” Grant has put his engineering expertise to the test as a star/producer of Netflix’s “White Rabbit Project” and star of the Verge digital series “Home of the Future.” Grant spent nine years working in special effects as an animatronics engineer and modelmaker for George Lucas’ Industrial Light and Magic.

**Ben Hilburn**
Director of Engineering, DeepSig Inc. and President, GNU Radio

Ben Hilburn is the Director of Engineering at DeepSig Inc., which is advancing the use of machine learning for RF and signal processing, and the President of GNU Radio, the world’s largest open-source software radio toolkit. Previously, he ran R&D at Ettus Research and was responsible for the Universal Software Radio Peripheral (USRP) product family.
**EVENT STRUCTURE**

- Each elimination round starts with round-robin matches
- The two lowest ranked teams teams after the round-robin compete in a knockout match
- The losing team in the knockout match is eliminated from the tournament

**How a match is scored:**

- Five teams compete in each match
- Teams score points each second by delivering data
- The bonus threshold represents the team's fair share of the spectrum
  - Teams receive all the points they earned when all teams in a match are scoring above the bonus threshold
  - If any team is scoring below the bonus threshold, all teams in the match receive only as many points as the lowest scoring team

<table>
<thead>
<tr>
<th>Rank of Team in Match</th>
<th>Prize</th>
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<tbody>
<tr>
<td>1</td>
<td>10 points</td>
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<tr>
<td>2</td>
<td>8 points</td>
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<td>3</td>
<td>7 points</td>
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<td>4</td>
<td>6 points</td>
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<td>5</td>
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In the final round, five teams compete in a series of matches
- In each match, teams earn prize points (see table)
- Prize points are summed to determine prize winners

**Final Round**
OVERVIEW OF SCENARIOS

The SCE competition tests the SC2 teams’ radio networks in a series of scenarios that mimic the real world challenges facing collaborative autonomous radios.

Round 1: Alleys of Austin
Can SC2 autonomous radios provide STABLE service without dedicated spectrum?

The Alleys of Austin Scenario represents a practice sweep of a residential neighborhood by dismounted soldiers.

Round 2: Off The Cuff
Can SC2 networks detect and exploit opportunities for SPECTRUM REUSE to increase capacity?

In a disaster relief situation, multiple aid and recovery teams will arrive on-site before a communication plan is established. Determining who can communicate on which channels becomes a challenge. In this scenario, each team has nodes in three zones of a city. Leveraging geographic separate, successful teams will learn how to reuse spectrum between their separated nodes, or ideally, how to reuse spectrum occupied by distant nodes of other teams.

Round 3: Wildfire
Can SC2 networks collaborate to dynamically PRIORITIZE traffic?

This scenario tests the ability of SC2 radios to handle priority traffic. Military and first responders face some of the most stressing spectrum usage environments. Slow manual spectrum allocation has proven problematic in unplanned and highly time-sensitive emergency operations. The Wildfire scenario investigates whether the SC2 networks can dynamically prioritize traffic and spectrum within and across teams.

Round 4: Slice of Life
Can SC2 networks collaborate to autonomously reallocate spectrum to HANDLE SURGES in demand?

Everyone has felt the frustration of using slow WiFi at a coffee shop during peak hours. This scenario is situated in an outdoor shopping mall, where each team’s network mimics a wireless hotspot. The scenario explores how artificially intelligent radios sense and adapt to the kinds of temporal surges in spectrum demand typical of high-traffic public environments.

Round 5: Trash Compactor
Can SC2 radios maintain quality of service in increasingly CONGESTED ENVIRONMENTS?

As spectrum grows every more congested, radio networks are challenged to carry more traffic using less bandwidth. This scenario tests the ability of SC2 radios to adapt their behavior as the available bandwidth shrinks further and further.
GAME VISUALIZATION

DARPA has developed a revolutionary spectrum visualization tool that provides spectators a view into the virtual stadium where the SC2 competition takes place. Each match is processed through this visualizer to enable in-depth analysis of collaborative AI radio performance.

Spatial View
Shows where the radio nodes are and how they are impacted by the scenario

- Each column displays a type of application data traffic
- Colored blocks represent individual data flows
- Colored blocks drop to the bottom when a data flow has been sustained for long enough to start scoring points

RF View
Shows each teams' RF spectrum usage moment-to-moment
MEET THE TEAMS

Andersons

Unaffiliated
One of SC2’s smallest teams, members of Andersons also won the 2014 DARPA Spectrum Challenge. Their approach here takes a page from autonomous vehicles - they create autonomous “self-driving” radios that navigate congested spectrum avoiding collisions and aggressive behavior.

Dragon Radio

Drexel University
The Dragon Radio team applies their expertise across multiple engineering disciplines to develop the next generation of software-defined radios. Their motto is: “mostly brawn and a modicum of brains.”

Erebus

Erebus Solutions Inc.
Applying years of experience building military radios, Erebus Solutions Inc. is a three person company created specifically to tackle SC2. This team of radio enthusiasts out of Rochester, New York, poured three years of passion into creating a unique design that exploits small bandwidth “scraps” left unused by other teams.

GatorWings

University of Florida
GatorWings is a team of undergrad students, Ph.D. candidates, and professors going one step beyond basic rule-based systems, applying foundational reinforcement learning AI techniques to optimize each “pocket” of spectrum it can get its hands on.

How Make Radio

Agitator, LLC
Two independent radio hackers with non-traditional engineering backgrounds—embrace the principle of “designing for failure” through decentralized decision-making that empowers every radio in their network to optimize its own performance.
MarmotE
Vanderbilt University • University of Szeged • Budapest University of Technology and Economics
A team of former and current Vanderbilt researchers, MarmotE eschews the popularity of deep learning and instead uses their radio expertise to separate what people are good at versus what AI is good at, creating a pool of advisors that promotes competing or collaborating solutions.

SCATTER
imec-IDLab • Ghent University • University of Antwerp • Rutgers University
Team SCATTER, true to its name, is not only scattered across the globe but also scattered across the spectrum. Their fully distributed approach adapts run-of-the-mill 4G/5G waveforms by nimbly moving across the spectrum, finding and predicting any open hole, and consuming any resource left unused.

Sodium-24
Unaffiliated
The new kid on the Software Defined Radio block. A one-man team with no prior wireless experience, he quit the work-a-day world of software engineering to devote the last three years to building radios using the same technology that taught machines to play Go.

Sprite
Northeastern University
In a world without the FCC, Sprite, a team of professors and Ph.D. students, has formulated spectrum sharing as a multiplayer game of Spectrum Tetris where the rules can change at any moment. To solve this intractable problem, Sprite uses machine learning to discover how others are playing the game on the fly.

Zylinium
Zylinium
Zylinium is the leopard that changes its spots; coupling robust interference-resilient waveforms with autonomy, it tailors the way it uses the spectrum depending on the radio networks it shares with.
DARPA announces Spectrum Collaboration Challenge (SC2) and development of Colosseum begins.

Colosseum opens its virtual doors at Johns Hopkins University Applied Physics Lab. The first SC2 Preliminary Event takes place in December.

DARPA awards prizes to six teams during the second SC2 Preliminary Event. Colosseum grows to become world’s largest RF channel emulator.

Colosseum moves from JHU APL to MWC 2019 Los Angeles for the SC2 finale. Final prize matches conducted live from the MWC show floor.

Colosseum transitions to NSF Platforms for Wireless Research (PAWR) Program to serve as a national wireless research asset.
Traditionally, spectrum managers like the Federal Communications Commission assign licenses to each wireless network or user. Each network or user has exclusive use of a frequency range in a particular geographic area. SC2 envisions an alternative approach, collaborative sharing, where a shared band is assigned to multiple networks. No central authority or control system is used. The networks collaborate among themselves to automatically avoid interference.

Collaborative sharing relies on wireless networks that can flexibly use the RF spectrum. The networks built for SC2 can quickly change how much spectrum they use over a wide range. They can split transmissions up into multiple channels of varying size that are spread over the band, and can quickly change the frequency and size of each channel. They have advanced filters enabling them to tune close to other networks without interference.

Traditionally, independent wireless networks don’t talk to each other. In SC2, a new language called CIL (Collaborative Intelligent Radio Network Interaction Language) enables the networks to exchange information so they can make better decisions about how to share spectrum. The information includes what frequencies each network is currently using, how much and what kind of traffic it is carrying, how much interference it is getting, and what frequencies it plans to use next.

Finally, each network contains an Artificial Intelligence (AI) decision engine. The AI decision engine figures out how to adapt the network’s spectrum use to maximize performance and to effectively collaborate with other networks. SC2 competitors use multiple types of AI, ranging from Expert Systems to Reinforcement Learning to Neural Networks. The SC2 Championship Event will help determine which type of AI is best for collaborative sharing.
**WHAT’S NEXT**

**Collaborative Intelligent Radio Networks:** Competitors own the Intellectual Property associated with the wireless networks and AI decision engines they have developed. DARPA looks forward to the exciting things they will do with the technology, including founding new companies, presenting scientific publications, and partnering with existing vendors to stimulate valuable new product lines.

**Collaborative Intelligent Radio Network Interaction Language (CIL):** The CIL is the technology enabling independent wireless networks to collaborate when sharing spectrum. SC2 intends to open-source the CIL and provide it to industry participants interested in standardization or utilizing it as a basis for further development.

**Colosseum:** Following the conclusion of MWC19 Los Angeles, the world’s most powerful RF emulator will become a national research asset supporting academic, industry, and defense exploration of wireless networks. Colosseum will become part of the Institute for the Wireless Internet of Things at Northeastern University in support of the National Science Foundation-sponsored Platforms for Advanced Wireless Research (PAWR) program. Availability for general research use is anticipated by summer 2020.

**Outdoor Tests using 5G Radios:** Through joint sponsorship by DARPA and interested industry participants, some of the successful SC2 competitors will be invited to participate in outdoor, over-the-air tests of collaborative spectrum sharing. Participants will conduct experiments such as using their AI decision engines to manage the spectrum use of standard 5G radios. Tests are expected to occur in 2020 at the POWDER testbed, a Salt Lake City, Utah site operated by the University of Utah under the National Science Foundation PAWR program.

*Organizations interested in sponsoring and shaping these tests are invited to contact SC2@darpa.mil.*

**DOD 5G Initiative:** 5G is a critical technology for the United States and its allies both economically and from a national security perspective. The US Department of Defense is launching a broad initiative to accelerate US deployment of, and leadership in, 5G and related technologies. This initiative will harness emerging technologies to enhance military capabilities and accelerate US deployment of new commercial products and services enabled by 5G networks. Key focus areas are security, dynamic spectrum sharing in congested environments, open standards and development of innovative enterprise applications that have both military and commercial relevance.

For more information, please contact SC2@darpa.mil.
For more than 60 years, the Defense Advanced Research Projects Agency has held to a singular and enduring mission: to make pivotal investments in breakthrough technologies for national security. In close collaboration with our Defense R&D partner agencies, DARPA engages top-tier public and private innovators - including academics, companies large and small, and colleagues across the federal government - to deliver on that mission, transforming revolutionary concepts and even seeming impossibilities into practical capabilities.

For additional information, please visit [www.darpa.mil](http://www.darpa.mil).
Additional SC2 Events

Thursday, October 24

Visit the SC2 Booth
9:00 am - 3:00 pm
Booth 1046

5G and Spectrum Sharing Panel
11:00 am - 12:00 pm
5G Talks Theater

SC2 Winners Panel
12:15 pm - 1:15 pm
5G Theater