

Spectrum Collaboration Challenge

SC2 Championship Event (SCE) Scoring Procedures

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DRAFT



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Revision Summary

Revision	Date	Description
1	February 1, 2019	(DRAFT) Initial Release for SCE

1 Overview

This document defines a set of scoring procedures for the SC2 Championship Event (SCE). These procedures apply to all participants in SC2. Further refinements and clarifications to this document will be released as needed. Prior to the SC2 Championship Event, a final scoring document will be released. That document will be clearly marked FINAL, all others will be marked DRAFT. The Final Scoring Procedures document will carry the full authority of the rules in the SC2 Rules document as outlined in Section 8 of the SC2 Rules.

The Scoring procedures laid out in this and any future version of this document are subject to change at DARPA's sole discretion as outlined in the SC2 Rules Document Section 7.1.

2 Tournament Scoring

SCE is composed of one or more rounds. The number of teams participating decreases from round to round until the final round, which determines the winners of the SCE. A round consists of two parts, Round-Robin and Knockout.

2.1 Round-Robin

The Round-Robin is a collection of matches played in one or more scenarios. A team's score in the Round-Robin is computed from its scores in the matches of that Round-Robin.

$$\text{Round-Robin Score} = \sum_i \text{Match Score in match } i$$

At the conclusion of the Round-Robin, team rankings are determined using the Round-Robin Score only.

2.2 Knockout

In the Knockout, each team plays one match.

Details of the Knockout procedures will be forthcoming in a future update to this document.

At the conclusion of the Knockout, team rankings are determined using the Knockout Score only.

2.3 Placeholder teams

Teams not participating in a Round-Robin or Knockout may be present in one or more matches, to fill out a scenario and provide opportunities for collaboration. Teams included for these purposes are not scored.

2.4 Tournament structure

In each round other than the final round, the higher ranked teams in the Round-Robin ranking advance directly to the next round. The lowest teams in the Round-Robin ranking must participate in the Knockout. The lowest teams in the Knockout ranking are eliminated.

The number of teams in the Knockout for each non-final round, and the number of teams eliminated in each round, will be announced as part of the final tournament structure. If more than one team is eliminated in a round, the lowest ranked team in the Knockout ranking is eliminated first, then the next lowest, and so on. This affects the final tournament ranking as described below.

The final round consists of a Knockout only.

2.5 Tournament Ranking

The final tournament ranking of the N teams that entered the tournament is determined as follows, if there are m teams participating in the Final Round:

Tournament Rank	Team
1 to m	Ordered according to the Final Round Knockout ranking
$(m + 1)$ to N	In reverse order of elimination from the tournament

3 Match Score

Each SCE match is divided into *stages*. During a stage, each network is given a number of *individual mandates (IM)*. An IM specifies the required wireless communications performance parameters for a particular IP traffic flow, and an associated number of points. A team can earn the points specified for that flow in each *measurement period* of time that it carries the flow, after an initial *steady state period*. A team's match score is the sum of the points earned in all measurement periods of the match that are not declared to be *unscored measurement periods*.

There is a pre-established threshold at which the ensemble must perform. The threshold for each team is a fraction of the maximum possible points that team could earn in each measurement period. When the lowest performing team is below its threshold, each team earns only the points scored by the lowest performing team (the *ensemble score*). When the lowest performing team is above the threshold, each team has the opportunity to earn bonus points based on its individual performance, irrespective of the performance of other teams.

In addition to IMs, scenarios have *gates*. A gate is a required behavior not associated with an individual IP traffic flow. A network cannot meet the required parameters of any of its IMs when a gate is being violated. Thus, no network earns points in measurement periods during which there is a gate violation, or during the following steady state period for each of its flows.

The following sections detail the above outlined scoring procedure.

3.1 Match Score Formulas

Measurement Period (MP): An MP is an interval of time in a stage over which performance parameters are assessed. The length of the measurement period (MP) for SCE is 1 second. All times t referred to in the below are discretized to MP .

Scored MP: A scored MP is one in which teams may earn points. In unscored measurement periods, no team's score is modified irrespective of gates met or IMs achieved.

Gates: A gate is a required behavior not associated with an IP traffic flow. A gate is met if the network or ensemble complies with the required behavior.

Performance Thresholds (PT): A PT is a required behavior of an IP traffic flow, such as required throughput or latency. The PT is deemed to be met in a given MP if the associated parameter meets or exceeds the specified threshold in that MP.

During a given MP, if no IP packets are offered, or if the parameters of a PT do not require the delivery of IP packets, the following conditions hold:

- The PT is deemed to be met if it was met in the previous MP.
- The PT is deemed to be not met if it was not met in the previous MP.

Individual Mandates (IM): An IM i provided to a network specifies the following: one or more PTs for an IP traffic flow, an associated point score P_i , and a steady state period SSP_i . An IM is deemed to be achieved at time t if all of the following conditions hold.

- The specified PTs are met in that MP
- The specified PTs have been continuously met in the preceding SSP_i MPs.
- No gate is violated in that MP

Note: SSP_i may be any positive value, including 0.

Measurement Period Score (MPS): The MPS is the total points associated with the IMs achieved in one MP by a single network.

$$MPS_t = \sum_{IMs\ i} S_{i,t}$$

where

$$S_{i,t} = \begin{cases} P_i, & \text{if IM } i \text{ achieved at time } t \\ 0, & \text{if IM } i \text{ not achieved at time } t \end{cases}$$

Relative Measurement Period Score (RMPS): The RMPS reflects the percentage of traffic carried by a network in a single MP.

$$RMPS_t = \frac{MPS_t}{\sum_i P_i}$$

Ensemble Threshold (ET): The scenario specifies an ET for each stage. The ET is provided to all networks.

Points Earned (PE): In the MP at time t , network N earns $PE_{N,t}$ points.

$$PE_{N,t} = \begin{cases} MPS_{m,t} & \text{if } RMPS_{m,t} < ET \\ MPS_{N,t} & \text{if } RMPS_{m,t} \geq ET \end{cases}$$

Where m is the lowest performing network of the ensemble:

$$m = \underset{\text{networks } j}{\operatorname{argmin}} MPS_{j,t}$$

Match Score: The Match Score for network N is:

$$\text{Match Score}_N = \sum_{\text{Scored MPs } t} PE_{N,t}$$

3.2 Individual Mandates

An *IP traffic flow* is a unique instance of IP traffic of a single application layer type to be delivered between source and destination IP addresses that are both in the team's network.

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An Individual Mandate (IM) has the following components:

- 1) A Flow Unique Identifier (flow UID) that identifies an instance of a specific traffic type, a source IP address, and a destination IP address.
- 2) Performance Thresholds (PT) for the IP traffic flow.
- 3) A Steady State Period (SSP)
- 3) A point score (P) that can be earned in each measurement period

The PTs and their associated interpretation are given in Table 1. The below performance thresholds are computed by the scoring subsystem for each Measurement Period (MP) during the match.

Table 1 – Performance Thresholds and associated scoring interpretation.

Performance Threshold	Description
<i>max_latency_s</i>	The maximum allowed latency (in seconds) for any IP packet in the flow during the measurement period.
<i>min_throughput_bps</i>	The minimum allowed throughput for the flow during the measurement period.
<i>file_transfer_deadline_s</i>	The maximum allowed latency (in seconds) for 100% of the packets of a file transfer to occur.

Throughput is measured as bits per second of IP traffic delivered to the traffic generator sink at the destination node.

Packet latency is measured from when the traffic generator source provides a packet to the source node to when the traffic generator sink receives it from the destination node. A packet which is not delivered in less than *max_latency_s* is considered dropped, decreasing the measured throughput, even if it is eventually delivered.

File transfer latency is measured from when the traffic generator source provides a packet to the source node to when the traffic generator sink receives it from the destination node. Latency is measured on a per packet basis. 90% of packets offered in a MP must be delivered in order to meet the PT. A packet which is not delivered in less than *file_transfer_deadline_s* is considered dropped.

The flow types and their associated default point scores are given in Table 2.

Table 2 – Flow Types and Default Point Values

Flow Type	Points
BFT	1
FTP	3
Imagery	2
SMS	1
UAV Control (C2)	4

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Video (continuous)	10
Voice	4
Web page download	9
Web page request	1

Note: Point values may vary from those above to emphasize priority of specific classes of traffic or specific flows.

3.3 Gate: Incumbent Protection

An *Incumbent* is a radio spectrum user that must be afforded protection in the spectrum. In scenarios with Incumbents, protecting the Incumbent is a gate for the mandated outcomes.

An *informing Incumbent* is one that provides feedback via the collaboration network to inform other radio networks if its threshold has been violated. Informing incumbents may have a threshold set as a function of acceptable interference power, or have a threshold based on acceptable degradation of nominal throughput.

In either case, an informing incumbent will advertise both its current threshold (interference power in dBFS, or minimum throughput in bps) as well as its current measurement against the threshold (interference power in dBFS, or achieved throughput). These reports will be sent every *Reporting Period*. A *Violation Period* is comprised of a number of successive Reporting Periods. The current threshold will not change during a Violation Period. If the average of the reported measured values over the Violation Period exceeds the current interference power threshold, or is below the minimum throughput threshold (whichever is applicable), the Incumbent is deemed to have experienced interference during that entire Violation Period. This is referred to as an *Interfering Violation Period*.

The *incumbent protection gate (IPG)* is deemed to be met during an MP, if no Violation Period in or overlapping that MP is an Interfering Violation Period.

3.4 Gate: Transmission Only in Allowed Bandwidth

RF transmissions are only permitted within the allowed bandwidth of each scenario. Respecting the allowed bandwidth limit is an additional gate for the mandated outcomes.

A transmission outside the allowed bandwidth is determined according to the following equation, with variables as defined in Table 2:

$$PSD(f_{disallowed}) > \Gamma$$

Table 2: Variables for determining transmission outside of allowed bandwidth

Variable	Description	Value in PE2
$PSD(f_{disallowed})$	The power spectral density of any transmitting node at frequency $f_{disallowed}$ as observed by the observer node with 0 dB of digital attenuation (see Figure 1)	<i>variable</i>
Γ	Transmission energy threshold referenced to full scale (dBFs). "Full scale" refers to the maximum signal that can be represented by the observer A/D converter.	-141 dBFs/Hz

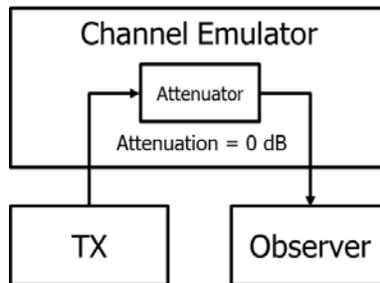


Figure 1 – Configuration of observer node

Multiple power spectral density observations will be taken of the transmissions of each node within a measurement period by an observer. Each PSD observation will average the power received over a time window. The length of the time windows is not specified in advance and may change during the course of a match.

The receiver gain of the observer node will be set according to Table 3 below. The gain of the closest center frequency to that of the scenario is used.

Table 3: Observe Node Receiver Gains

Center Frequency	Observer Receive Gain
1.0 GHz	7 dB
2.4 GHz	8 dB
5.8 GHz	15 dB

The transmission bandwidth gate (TBG) is deemed to be met during an MP if no transmissions beyond the allowed frequency bandwidth are detected within that MP.

4 Feedback to networks

A team’s network does not receive real-time feedback on scoring. Specifically, the system does not inform the network whether any IM has yet been achieved in the current stage, or whether applicable gates have been met.