Spectrum Collaboration Challenge

Preliminary Event 1 Scoring Procedures

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Revision Summary

Revision	Date	Description
1	May 19, 2017	(DRAFT) Initial Release for PE1
2	September 15, 2017	(DRAFT) Updated Scoring for PE1
3	October 2, 2017	(DRAFT) Updated Section 3 to include the mapping between Traffic Class and IP TOS field values Updated Section 4 to include the observer gain settings
4	October 31, 2017	(DRAFT) Updated Section 3 calculation of average latency
5	November 28, 2017	FINAL – NO CHANGES

1 Overview

This document defines a draft set of scoring rules for SC2 Preliminary Event #1 (PE1). The scoring rules apply to all participants in SC2. Further refinements and clarifications to the scoring rules will be released as needed. Prior to each Tournament event, a final scoring document applicable to that event will be released. This 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 outlined in the SC2 Rules Document Section 7.1.

2 Tournament Score

A team's overall tournament score is a weighted sum of their match scores, S_i^M, computed using the following formula:

$$TS_i = \sum_{M \in \mathcal{M}} \frac{1}{N_M} S_i^M$$

where:

- S_i^M is the score of team i in match M
- N_M is the total points that could possibly be scored by team i in match M
- $\mathcal{M}$ is the set of all matches played by team i

The Tournament Score TS_i, is the sole metric used to compute competition ranks, and thus determine awarding of prizes, for PE1.

3 Overall Match Score

The score *S* for a competitor network *i,* in a match *M* is evaluated over a series of intervals m:

$$S_i^M = \sum_{m \in M} S_i(m)$$

A match interval m, corresponds to a period of time during a scenario. The maximum length of a match interval is 10 seconds. Shorter intervals may be used.

3.1 Match Interval Score

The score for competitor i for match interval m, denoted $S_i(m)$, is computed using the following formula:

$$S_i(m) = \underbrace{\rho_i(m)}_{\text{penalty}} \times \left[\underbrace{P_i(m)}_{\text{Own-network Performance}} + \underbrace{P_{PEER}(m)}_{\text{Collaboration Performance}} \right]$$

where:

- $P_i(m)$ measures success at delivering the traffic offered to one's own network
- $P_{PEER}(m)$ measures success of other competitors at delivering traffic offered to their networks
- $\rho_i(m)$ reduces the score when penalties such as for out-of-band transmission apply

3.2 Communications Performance

A communications network's performance is measured by various Quality of Service (QoS) metrics, depending on the class of traffic. For PE1, DARPA will offer traffic flows of up to four classes:

1. Voice Over IP (VoIP) – mimicking packetized voice delivery over IP networks
2. "Leaky Bucket" – a "bucket" which sends packets at a fixed rate or according to a distribution
3. File Transfer Protocol (FTP)
4. Hyper Text Transfer Protocol (HTTP)

The traffic class type of a packet will be given by the lower 4 bits of the IP Type of Service (TOS) field as outlined in the below table:

Traffic Class	TOS value
"Leaky Bucket"	0
VoIP	1
FTP	2
HTTP	3

Overall communications performance is the weighted sum of normalized QoS metrics for each offered traffic flow.

$$P_i(m) = \sum_{t \in T_i} \alpha_t \pi_t Q_t(m)$$

where

- $Q_t(m)$ is the QoS of end-to-end traffic flow *t* during match interval *m*
- T_i is the set of all end-to-end traffic flows (of all nodes) of team *i*
- π_t is a scaling term associated with the priority PRI_t of traffic flow t. π_t is derived from the formula below based on the priority value PRI_t given in the upper 4 bits of the IP Type of Service (TOS) field.

$$\pi_t = 1 + \frac{PRI_t}{10}$$

- α_t is the relative weight given to successful delivery of traffic flow t. The table below gives the values of α_t for PE1.

Traffic Class	α_t
VoIP	7.5
"Leaky Bucket"	1
FTP	1
HTTP	2.5

Table 1 – Traffic class weighting values

3.2.1 Quality of Service Definition

In PE1, the QoS metric for traffic flow t in match interval m, $Q_t(m)$, is a function of constrained average packet latency of flow t in interval m, $\overline{L_t}(m)$. It is defined by the following piecewise-linear function:

$$Q_t(m) = \begin{cases} 1 & \overline{L_t}(m) \leq L_c^{MIN} \\ 1 + \dfrac{(L_c^{MIN} - \overline{L_t}(m))}{(L_c^{MAX} - L_c^{MIN})} & L_c^{MIN} < \overline{L_t}(m) \leq L_c^{MAX} \\ 0 & \overline{L_t}(m) > L_c^{MAX} \end{cases}$$

where:

- The latency (L) of a packet is the time duration measured by the traffic generation system from packet source to packet sink.
- "Packet" refers to an IP packet up to 64KB in size
- L_c^{MIN} is the minimum average latency for traffic class c where no additional points are awarded for faster delivery
- $L_c^{MAX}$is the maximum average latency for traffic class c that packets can be delivered and still receive points
- $\overline{L_t}(m)$ is the average of $\min(L, L_c^{MAX})$ for all packets of flow t over match interval m (this ensures the average isn't overly skewed by large latencies beyond the maximum defined).

The following table shows the parameters used in PE1 for each traffic class.

Traffic class	L_c^{MIN} **(ms)**	L_c^{MAX} **(ms)**
VOIP	150	800
"Leaky Bucket"	10	4100
FTP	125	4000
HTTP	25	800

The resulting shape of the QoS metric is shown in the following figure.

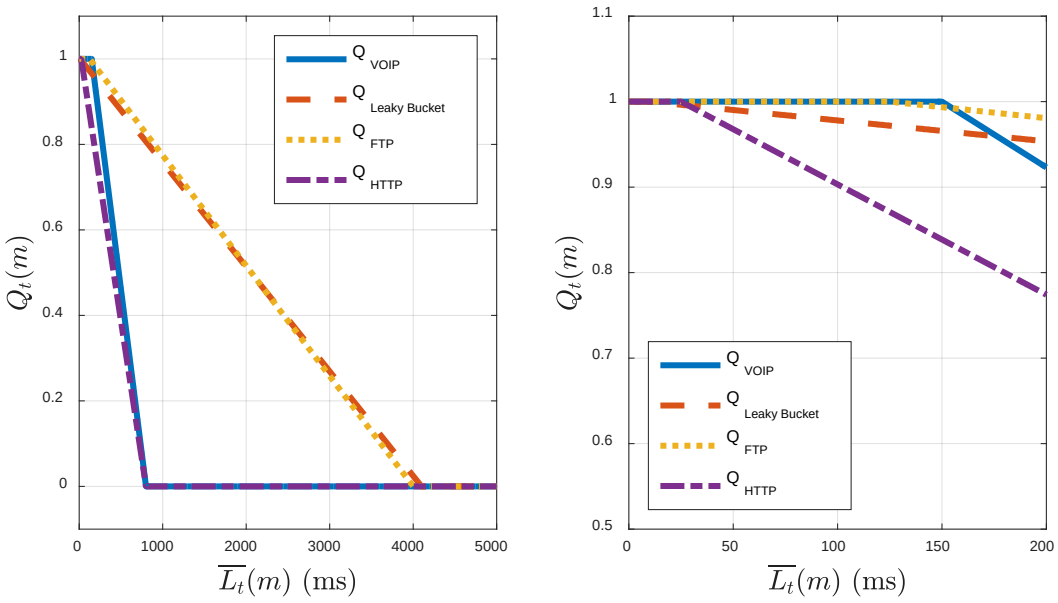

Figure 1 – Value of $Q_t(m)$ with average latency $\overline{L_t}(m)$ between [0, 5000] ms (left) and [0, 200] ms (right)

3.3 Collaboration Performance

The collaboration performance score is computed using the same communications performance formulas described in Section 3.2. Communications performance is assessed for the other competitor networks. These are combined as follows:

$$P_{PEER}(m) = \sum_{j}^{N_P} w_{ij} P_j(m)$$

where

Variable	Description	Value in PE1
N_P	the number of peer networks	2
w_{ij}	the collaboration weight of team j to team i	$\frac{1}{N_p}$
$P_j(m)$	the communications performance score of team j in match interval m	*variable*

4 Penalties

4.1 Penalizing Transmissions in Disallowed Frequencies

Competitors will be assessed a penalty for transmitting outside the allowed frequencies for a given scenario. The penalty assessed for team i during match interval m is given as follows:

$$\rho_i(m) = \begin{cases} 0 & PSD_{i,n}(f_{disallowed}) > \Gamma \\ 1 & otherwise \end{cases}$$

where

Variable	Description	Value in PE1
$PSD_{i,n}(f_{disallowed})$	The power spectral density of transmitting node n of team i at frequency $f_{disallowed}$ as observed by the observer node with 0 dB of digital attenuation (see Figure 2)	*variable*
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

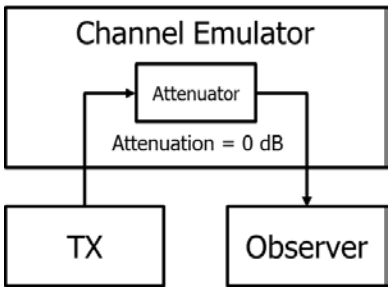

Figure 2 – Configuration of observer node

Multiple power spectral density observations will be taken of the transmissions of each node n within a match interval m 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 penalty ρ_i is assessed if any of the nodes n of the network i violate the threshold Γ for any disallowed frequency during any time window within the match interval.

The receiver gain of the observer node will be set according to the below table. The gain of the closest center frequency (see below table) to that of the scenario is used.

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