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The Quantum Computing Company™

D-Wave Release Notes

09-1045A-I

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CHAPTER

ONE

INTRODUCTION

Intended Audience

This document is intended for users of the D-Wave™ system. This includes:

- End-users of the system who interact with the system via the Qubist web user interface or any of the supported client libraries: C, MATLAB, or Python.
- Resource managers and system administrators who interact with the system via the Qubist web user interface.

Scope

This document describes the latest release of the solver application programming interface (SAPI) web services components, including the Qubist web user interface, as well as changes to the SAPI client libraries. It includes a list of the new features in the release, describes any changes to default system behavior, and lists any known or resolved issues that may affect your use of the D-Wave system.

To see the SAPI releases at a glance, and to see whether a particular release introduces changes to the client libraries, refer to the *Release Summary* chapter.

Related Documents

See also the following related documents, all of which are available on the Qubist web user interface:

- *Measuring Computation Time on D-Wave Systems*
- *Technical Description of the D-Wave Quantum Processing Unit*
- *Postprocessing Methods on D-Wave Systems*
- C, MATLAB, and Python developer guides, which describe the APIs used for programming a D-Wave system
- *D-Wave System Administrator Guide*[1]

[1] Available only to users with resource manager or system administrator privileges.

Revision History

Revision	Date	Summary of Change
09-1045A-I	2017-03-15	Updates for SAPI Release 2.10.3.
09-1045A-H	2017-01-09	Added this revision history table and the feature summary chapter.
09-1045A-G	2017-01-06	Minor corrections.
09-1045A-F	2016-12-06	Updates for SAPI Release 2.10.
09-1045A-E	2016-10-31	Updates for SAPI Release 2.8. Merged separate release notes into this single document.

CHAPTER

TWO

RELEASE SUMMARY

This table summarizes the Solver API (SAPI) features by release, and indicates which releases affect the C, MATLAB, and Python client libraries. The latest versions of the client libraries are available on the Qubist web user interface. If you are upgrading to a release that includes changes to the client libraries, visit the **Resource Downloads** page to access the new versions.

Rel.	Features	Client Update	Notes
2.10.3	• *Beta Parameter Now Available in Qubist* • *Qubist Changes to Support VFYC Solvers* • *Changes to Postprocessing Defaults for VFYC Solver*	No	Release 2.10.3 is the current version of SAPI web services components. Note that the SAPI clients are on Release 2.6.
2.10	• *Deprecated readout_thermalization Parameter* • *New Documents: QPU Properties per System*	No	
2.9	N/A	No	No customer-facing changes.
2.8	• *Statistics Improvements* • *Usability Improvements for Problem Definition*	No	
2.7	N/A	No	No customer-facing changes.
2.6	• *Improved Color Map* • *Support for Multiple Solver Scheduling* • *Support for Custom EULA* • *Support for Notifications by Project* • *Changes to Quota Expiration* • *Changes to Documentation Packaging* • Internal client infrastructure enhancements	Yes	Release 2.6 is the current version of the SAPI client libraries available for download from the Qubist web user interface.
2.5	• *Support for Anneal Offsets*	Yes	
2.4	• *Enhancements to System Timers* • *Multiple Spin-Reversal Transformations* • *New Solver: Virtual Full-Yield Chimera* • *New Error-Handling Functions* • *Fixed-Time User Quota* • *Support for LDAP Credentials* • *Changes to Solution Data in Qubist* • *New Documents*	Yes	

CHAPTER

THREE

RELEASE 2.10.3

New Features

Beta Parameter Now Available in Qubist

When submitting sampling problems, users can specify inverse temperature β using the `beta` parameter in SAPI. The sampling postprocessing algorithm uses this value to affect the statistics of the Boltzmann distribution of the returned solutions.

The `beta` parameter has been available in the SAPI client libraries for many releases. New in this release is the ability to specify this value via the new **Beta** field in the **Submit Problem** page in the Qubist web user interface.

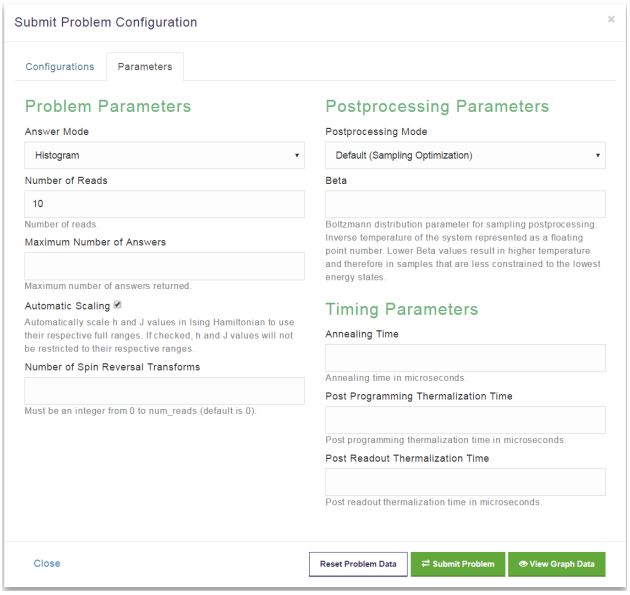

Fig. 3.1: Beta parameter available in the Qubist web user interface for sampling problems.

Note: As in statistical mechanics, β represents inverse temperature: $1/(k_B T)$, where T is the thermodynamic temperature in kelvin and k_B is Boltzmann's constant. In the D-Wave software, postprocessing refines the returned solutions to target a Boltzmann distribution characterized by β, which is represented by a floating point number without units. When choosing a value for β, be aware that lower values result in samples less constrained to the lowest energy states. For more information on β and how it is used in the sampling postprocessing algorithm, see *Postprocessing Methods on D-Wave Systems*.

Qubist Changes to Support VFYC Solvers

This release introduces changes to Qubist to better support virtual full-yield (VFYC) solvers, first introduced in Release 2.4 (see *New Solver: Virtual Full-Yield Chimera*):

- The **Solver Properties** page now identifies whether the solver is a VFYC solver.
- The **Submit Problem** page no longer lists "None" as a postprocessing option for problems submitted to a VFYC solver. (Postprocessing is always required for problems submitted to these solvers.)

Changes to Default System Behavior

Changes to Postprocessing Defaults for VFYC Solver

This release introduces changes to the default behavior of VFYC solvers. As of Release 2.10.3, the sampling postprocessing algorithm runs by default, and the value of the `beta` parameter (relevant only for sampling postprocessing) defaults to `10`. In contrast, in previous releases, the optimization postprocessing algorithm ran by default for this solver and—if the sampling postprocessing algorithm was specified instead—the `beta` value defaulted to `1`.

Be aware that this change is not backwards compatible. Update any code that relies on the postprocessing or `beta` defaults for VFYC solvers as needed to get the behavior you want.

CHAPTER

FOUR

RELEASE 2.10

Changes to Default System Behavior

Deprecated readout_thermalization Parameter

While still supported in SAPI Release 2.10, the `readout_thermalization` parameter is deprecated and will eventually be removed from the API. Plan code updates accordingly.

Note: This user-specified parameter contributes to the `qpu_delay_time_per_sample` value returned via SAPI. Without `readout_thermalization`, the delay between anneals is a constant value.

New Documents: QPU Properties per System

As of Release 2.10, system-specific documents are available listing the properties of each calibrated D-Wave QPU. Available properties vary slightly per system, but may include:

- Number of couplers
- Qubit temperature (mK)
- $\mathrm{M}_{\mathrm{AFM}}$ (pH)
- Average single qubit thermal width
- Problem h range
- Problem J range
- Timing details
- Readout error rate
- $A(s)$ and $B(s)$ values

To obtain the properties of your system, contact D-Wave Support at dwsupport@dwavesys.com.

Known Issues

Problems Submitted to Software Solvers via Qubist UI

Problems submitted to a remote software solver via the **Submit Problem** page in the Qubist web user interface may return incorrect answers. This issue does not affect hardware solvers, local software solvers, or any problem submitted via the SAPI clients.

To avoid this issue, use the SAPI clients rather than the Qubist web user interface when submitting problems to remote software solvers.

CHAPTER

FIVE

RELEASE 2.8

New Features

This section describes the new features in this release.

Statistics Improvements

Release 2.8 introduces several enhancements to the display of the plotted statistics available in the Qubist web user interface. From the Statistics page, you can now perform the following additional operations to explore the data:

- Showing or hiding contributors to the visualized data
- Zooming in and out, including by region
- Panning across a region
- Autoscaling and resetting axes
- Displaying and comparing additional details by hovering over plot points

Usability Improvements for Problem Definition

When defining a problem through the Qubist web user interface, users can now directly specify the desired qubit weights and coupler strengths as an alternative to using the slider to set these values. This usability improvement makes it easier to set precise values.

Changes to Default System Behavior

Change to Statistics Refresh Default

Starting in Release 2.8, statistics in the Qubist web user interface are not automatically refreshed by default. Resource managers can enable this behavor if desired.

Documentation Changes

Previously, D-Wave provided separate sets of release notes per SAPI client. Starting in Release 2.8, release notes are delivered in a single document, now called *D-Wave Release Notes*.

CHAPTER

SIX

RELEASE 2.6

New Features

This section describes the new features in this release.

Improved Color Map

This release improves the colors displayed in the Chimera graph on the Qubist web user interface. This display-only enhancement does not affect system operation.

Support for Multiple Solver Scheduling

This release improves the internal scheduling in systems running multiple solvers. This improvement does not change system administration or problem management activities.

Support for Custom EULA

This release enables resource managers and system administrators to define an end-user license agreement (EULA) particular to your organization. Do so by configuring it as a *custom region* in Qubist. See the *D-Wave System Administrator Guide* for instructions.

Support for Notifications by Project

Resource managers and system administrators can now send notifications to all users assigned to a project.

Changes to Default System Behavior

This section describes the changes to default system behavior in this release.

Changes to Quota Expiration

This release introduces changes to when quotas expire. The new behavior is as follows, per reporting period:

- Fixed-Time — Quota expires after specified allocation has been spent on the QPU, regardless of elapsed clock or calendar time.

- Hourly — Quota expires at the start of every hour (:00), regardless of time spent on the QPU.
- Daily — Quota expires at 12:00 a.m. each day, regardless of time spent on the QPU.
- Weekly — Quota expires at 12:00 a.m. each Monday (just after midnight on Sunday), regardless of time spent on the QPU.
- Monthly — Quota expires at 12:00 a.m. on the first day of the month (just after midnight on the last day of the prior month), regardless of time spent on the QPU.

Changes to Documentation Packaging

Starting in Release 2.6, the D-Wave user documentation is no longer bundled with the Solver API client download packages. Retrieve the latest versions of the documentation from the Qubist web user interface.

Resolved Issues

This release resolves the following issues:

Table 6.1: Resolved Issues in Release 2.6.

#	Description
1568	The MATLAB `sapiUnembedAnswer` function may have produced incorrect results if the `brokenChains` parameter was set to `weighted_random` and the `embeddings` parameter contained a singleton chain (a variable mapping to a single qubit).

CHAPTER

SEVEN

RELEASE 2.5

New Features

This section describes the new features in this release.

Support for Anneal Offsets

In the standard application of quantum annealing in D-Wave systems, all qubits evolve simultaneously, experiencing equal changes to tunneling energy and making an equal contribution to the classical energy function. In some situations, however, it is beneficial to *offset* the annealing paths of the qubits, so that some are annealed slightly before others. This technique can improve both optimization and sampling performance for certain types of problems. Release 2.5 introduces a new user parameter and several new solver properties to support the anneal offsets feature.

New user parameter:

- `anneal_offsets`—Array indicating whether and by how many normalized offset units to modify the annealing path for each qubit.

New solver properties (values vary slightly by QPU):

- `anneal_offset_ranges`—Minimum and maximum shift possible per qubit, in normalized offset units.
- `anneal_offset_step`—Step size for the anneal offset in normalized offset units, typically ~0.005.
- `anneal_offset_step_phi0`—Step size of anneal offset in annealing flux bias units, Φ_0.

Note: Annealing offsets are not supported on D-Wave 2X and earlier systems. Before using this feature, query the solver properties using SAPI calls to determine whether it is supported and, if so, to obtain the available tuning ranges per qubit.

For the C client, this feature introduces:

- New `sapi_AnnealOffsets` data type to hold the `anneal_offsets` array.
- New fields in the `sapi_QuantumSolverParameters` and `sapi_SolverProperties` data types to hold the new solver properties.
- New `sapi_ParametersProperty` data type to list the allowed parameters for a solver. (Not all solvers support offset annealing paths.)

Documentation Changes

The following new documents are available on the Qubist web user interface in Release 2.5:

- *Getting Started with the D-Wave System*—Introduces the D-Wave system to new users.
- *Technical Description of the D-Wave Quantum Processing Unit*—Describes the physical implementation of the D-Wave QPU architecture, lists the factors that can affect results, and provides usage guidelines to help maximize performance.

The *Programming with QUBOs* document has been removed from the documentation package as of Release 2.5. Much of the content from this document is now covered in *Technical Description of the D-Wave Quantum Processing Unit*.

CHAPTER

EIGHT

RELEASE 2.4

New Features

This section describes the new features in this release.

Enhancements to System Timers

This release improves the timers that measure computational time on the D-Wave™ system and introduces changes to the related keywords for accessing timing information through the Solver API. These enhancements enable users to better measure and characterize system performance.

The new keywords are available in the client libraries and visible in the Qubist web user interface. The timing-related keywords in previous releases of the Solver API are deprecated (but still available) in Release 2.4 and will be unavailable in future releases. Plan updates to any code that uses the old keywords.

The following table maps old names to new ones:

Old name (deprecated)	New name
`total_real_time`	`qpu_access_time`
`run_time_chip`	`qpu_sampling_time`
`anneal_time_per_run`	`qpu_anneal_time_per_sample`
`readout_time_per_run`	`qpu_readout_time_per_sample`

New timing keywords in this release of the Solver API are as follows:

- `qpu_programming_time`
- `qpu_delay_time_per_sample`
- `total_processing_time`
- `post_processing_overhead_time`

For more information about timing, including descriptions of all timing-related keywords, see *Measuring Computation Time on D-Wave Systems*.

Multiple Spin-Reversal Transformations

Previous releases of the Solver API supported only a single spin-reversal transform. Release 2.4 adds support for multiple transforms to better support the needs of certain machine-learning and heuristic solvers. The maximum number of transforms possible equals number of reads specified when a problem is submitted.

New Solver: Virtual Full-Yield Chimera

This release introduces a virtual full-yield Chimera (VFYC) solver, which uses a hybrid algorithm to solve problems defined on a VFYC graph. Use it to prototype algorithms based on an idealized abstraction of the system without being concerned about missing qubits or couplers that might affect a given QPU. For problems submitted to this solver, postprocessing always runs to accommodate any missing qubits.

Note: Be aware that because the full-yield Chimera solver only emulates an ideal system, performance varies from system to system.

To understand how the optimization and sampling postprocessing methods work with results obtained via this new solver, see *Postprocessing Methods on D-Wave Systems*.

New Error-Handling Functions

Release 2.4 introduces new error-handling functions:

- Asynchronous retry function—Retries communication for asynchronous problems that have failed for non-solving reasons. For instance, network errors during communication with the SAPI server may cause problems to fail in the client, even though the problem might be solved successfully. This function forces the client to retry communication with the server.
- Asyncronous status function—Provides information about asynchronous problems, including solving status, communication status, error information, and submission and solve times.

Function names for each SAPI client are below.

Table 8.1: New error-handling functions.

C	MATLAB	Python
sapi_asyncRetry	sapiAsyncRetry	retry
sapi_asyncStatus	sapiAsyncStatus	status

Fixed-Time User Quota

As well as being able to assign user quotas for QPU access based on elapsed clock or calendar time (e.g., hourly, weekly, monthly, and so on), in this release resource managers and system administrators can now assign a fixed total time allocation to a user. This quota does not expire until the user has spent the allocated time on the QPU, regardless of elapsed time. For example, if assigned 10 hours of QPU time, a user could take this time all at once (in a 10-hour block) or over a much longer period.

Support for LDAP Credentials

In Release 2.4, users can log on to the Qubist web user interface using LDAP credentials (if configured by their resource manager or system administrator). Other means of authentication are still supported.

New Documents

Two new documents are available on the Qubist web user interface in Release 2.4:

- *Measuring Computation Time on D-Wave Systems* — Describes how timing works for problems submitted to D-Wave systems and identifies the timing-related fields available in the D-Wave Solver API. It provides a breakdown of the programming and sampling time to process a single QPU job, as well as the additional service time required.
- *Postprocessing Methods on D-Wave Systems* — Provides an overview of the optimization and sampling post-processing methods available, presents the results of a number of tests conducted by D-Wave, and describes the role of postprocessing in results obtained by the VFYC solver.

Changes to Default System Behavior

This section describes the changes to default system behavior in this release.

Changes to Solution Data in Qubist

For problems submitted with more than 1000 reads (num-reads), Qubist users can no longer access details of the solution through the web user interface (UI). Likewise, the solutions to such problems can no longer be visualized through Qubist. This change was made to preserve the performance of the UI. For such problems, the following Qubist components are unavailable as of Release 2.4:

- Problem Status > Solutions tab
- Visualize Data button

Regardless of the number of reads, users can still access all solution details through the Solver API client libraries as before.