PacBio

SMRT® Link software installation guide (v25.3)

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1305 O’Brien Drive Menlo Park, CA 94025

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Introduction

This document describes the procedure for installing **SMRT Link v25.3** or **SMRT Link Lite v25.3**. This document is for Customer IT or SMRT Link administrators.

- **SMRT Link v25.3** and **SMRT Link Lite v25.3** support Vega™ and Revio® systems. Sequel® II systems, Sequel IIe systems, and Sequel systems are **not** supported.

SMRT Link is the web-based end-to-end workflow manager for PacBio® long-read systems. It includes software applications for designing and monitoring sequencing runs and analyzing and managing sequence data.

SMRT Link is the primary access point for applications used by researchers, laboratory technicians, instrument operators, and bioinformaticians. The applications include:

- **Instruments:** View information about systems connected to SMRT Link.
- **Sample Setup**: Generate protocols for binding polymerase to SMRTbell libraries and diluting libraries for loading libraries on SMRT Cells.
- **Runs**: View information about sequencing runs, monitor run progress, status and quality metrics, design sequencing runs and create and/or import run designs.
- **Data Management**: Create Projects and Data Sets; manage access permissions for Projects and users; access QC reports for Data Sets; view, import, export, or delete sequence, reference, barcode and BED files.
- **SMRT® Analysis**: Perform secondary analysis on the data generated by the basecaller (such as sequence alignment, variant detection, structural variant calling, and RNA analysis) after a run has completed.
  Note: The SMRT® Analysis module is **not** included when you install **SMRT Link Lite**.

Note: SMRT Link, SMRT Link Lite, and the Vega, Revio, Sequel II, and Sequel IIe systems are for research use only (RUO).

Definitions and variables

For clarity, this document uses these conventions to refer to site-specific information:

- `$SMRT_ROOT`: The SMRT Link Install Root Directory, such as `/opt/pacbio/smrtlink`.
- `$SMRT_USER`: The SMRT Link Install User, such as `smrtanalysis`.
- `smrtlinkhost.mydomain.com`: The fully-qualified domain name of the SMRT Link Install Host.
- `hostname`: The short host name of the SMRT Link Install Host.

For `$SMRT_ROOT`, defining the variable in the shell allows the commands below to be run verbatim. For example,
`SMRT_ROOT=/opt/pacbio/smrtlink`

Overview

1. Install or upgrade the SMRT Link software. (See "Installation instructions" and "Upgrading SMRT "Upgrade instructions" for details.)
2. (**Optional**) Configure SMRT Link or SMRT Link Lite to use an SSL certificate. (See "Installing an SSL certificate for NGINX" for details.)
3. (**Optional**) Configure LDAP. (See "LDAP integration" for details.)
4. (**Optional**) Add SMRT Link Users and Assign User Roles. (See "Adding SMRT Link users via LDAP and assigning user roles" for details.)
5. (**Optional**) Change the admin password. (See "Changing admin and pbicsuser passwords" for details.)

System requirements and configurations

Operating system requirements

- SMRT Link server software is supported on the following English-language operating systems:
  - Rocky Linux 8 and 9.
  - Ubuntu 22.04 and 24.04
  - This also applies to SMRT Link compute nodes.
- SMRT Link is not guaranteed to work on operating system versions that are no longer supported by their vendors.
- SMRT Link server software cannot be installed on Mac OS or Windows systems.

Supported instruments

Instrument	Instrument software
Revio® system	Instrument software v13.3, all chemistries
Vega™ system	Instrument software v1.1.0, all chemistries
Sequel® II and IIe system	Not supported; a SMRT Link v13.1 installation is required.

Software dependency requirements

- SMRT Link server should run on a dedicated 64-bit Linux host with `libc 2.17` or greater.
- SMRT Link requires the Google Chrome web browser.
- Configuring your SMRT Link server with a Job Management System (JMS) is required if running SMRT Analysis workflows. SLURM is our supported JMS. For details on other JMS see the Appendix.
- Singularity v3.10.5 or later is required for the **Variant Calling** and **Target Enrichment** analysis workflows. The Target Enrichment workflow only requires Singularity if variant calling is enabled in the advanced parameters.
  - Singularity requires that SMRT Link is configured with a JMS.
  - We recommend installing Singularity as root, with the setuid bit enabled (chmod u+s singularity) in the /bin or /usr/bin directory. The singularity binary should then have -rwsr-xr-x permissions.
  - Because a SMRT Link server running SMRT Analysis should be configured to run with SLURM, we recommend installing the `singularity-ce` package on the SMRT Link server, as well as each of the nodes within the relevant partition where you are submitting jobs.
  - Singularity should not be installed in an NFS area of the file system.
  - The singularity binary cannot be installed to any file system area mounted with the `nosuid` and/or `noexec` mount options.
  - To run Variant Calling or Target Enrichment with variant calling turned on, Singularity requires the following Docker images
    - `docker://google/deepvariant:1.6.1;`
    - `docker://google/deepvariant:1.6.1-gpu;`
    - `docker://quay.io/biocontainers/whatshap:1.4--py39hc16433a_1;`
    - `docker://ghcr.io/dnanexus-rnd/glnexus:v1.4.1`
  - To save these images locally, we provide a script, `$SMRT_ROOT/admin/bin/fetch-singularity-cache`, which uses the root account to download the images, using `/tmp` as a temporary file space, before depositing the `.sif` files into `$SMRT_ROOT/userdata/singularity` and changing ownership to the requesting user. We recommend running this script after installing SMRT Link.
  - For further details on configuring Cromwell for Singularity, see here.

Hardware requirements and configuration

Component	SMRT Link multi-node configuration		SMRT Link single node configuration	SMRT Link Lite
	Head node	HPC node		
CPUs	8 cores	64 cores	16 cores/32 threads	4 cores
RAM	32 GB	4 GB per core	64 GB	16 GB
Local storage	500 GB SSD	100 GB SSD or HDD	1 TB SSD	50 GB SSD

Note: SMRT Link servers configured with HPC node(s) are required to support running Variant Calling analysis (standalone or within Target Enrichment) and larger Iso-Seq® Analysis jobs (>20M reads).

SMRT Link single node systems may require additional configuration. It is recommended to adjust the `concurrent_job_limit` to ensure that the number of concurrently running jobs does not exceed the available memory on your single node system. This can be set during install or by editing the configuration file `$SMRT_ROOT/userdata/generated/config/cromwell.conf`.

SMRT Link Lite is a modified configuration that uses the same installer and software as SMRT Link, but with the most compute-intensive components (SMRT Analysis) disabled to support running on non-server hardware.

Recommended analysis input size limits for a single node SMRT Link server configuration

Workflow	Limit with recommended single node server
HiFi Mapping	150 Gb
Target Enrichment	Disable variant calling
Iso-Seq Analysis	20 million reads
Microbial Genome Analysis	No limit
PureTarget repeat expansion	No limit
Read Segmentation	No limit
Single-Cell Iso-Seq	60 million reads
Variant calling	Not supported

Server environment requirements

- The installation is performed by the **same** non-root user (`$SMRT_USER`) that will be used to run the SMRT Link web services.
- The `$SMRT_USER` has full permissions recursively throughout the install directory, and in all linked directories for `jobs_root`, `db_datadir` and `tmp_dir`. Common problems include NFS setup problems, ACLs, and so on.
- When running in distributed mode, all other nodes have the **same path** for `$SMRT_ROOT` and for all linked directories. (The NFS exports should have identical mount points on **all** cluster nodes.)
- No other daemons/services processes are bound to the same ports as the SMRT Link services.
- PacBio **highly recommends** that the system clock be synchronized to a domain or public NTP time server.
- The `$SMRT_USER` service account **must** have both the `nofile` and `nproc` soft user limits set to a minimum of `8192`. (See the `ulimit(1)` and `limits.conf(5)` Linux man pages for more information.)
- The host operating system **must** provide the `en_US.UTF-8` locale/character set.

- **SMRT Link** and **SMRT Link Lite** are **not** designed to handle changes in the hostname. If you are using them to connect to a Revio or Vega instrument you should ensure that the configured hostname is and will remain accessible across the network.

Network configuration

For network connectivity considerations, see the network diagram in Appendix.

Ports and firewalls

SMRT Link end users **must** be able to access the SMRT Link server on port `8243`. This port is also used by the Instrument Control Software (ICS), so it must be accessible to any Revio and Vega systems as well.

- If your network configuration already allows access to port `8243`, no additional changes are required to use SMRT Link v25.3 or SMRT Link Lite v25.3.
- The instrument must have access to TCP port `8243` of the SMRT Link server.
- End users must also have access to TCP port `8243` of the SMRT Link server for access to the browser UI.
- Communication between Revio and Vega instruments and SMRT Link is bidirectional, so SMRT Link **must** have access to TCP port `9243` on any associated Revio and Vega instruments.

SMRT Analysis configuration

- The SMRT Link software's installation **root** directory **must** be readable and writable by the SMRT Link install user (`$SMRT_USER`) and **must** be addressable along the same installation path (`$SMRT_ROOT`) on **all** relevant cluster nodes via NFS. PacBio recommends `/opt/pacbio/smrtlink` for the SMRT Link software's installation root directory (referred to as `$SMRT_ROOT`), and `smrtanalysis` for the SMRT Link install user (referred to as `$SMRT_USER`).
- The SMRT Analysis job **output directory** is used to store output from SMRT Analysis jobs. The software accesses this directory through a symbolic link (`$SMRT_ROOT/userdata/jobs_root`) that points to the desired job output directory location. The link can be modified by using the installation script. The symbolic link destination should be on a shared file system (NFS); it must be writable by the `$SMRT_USER`, and it must be addressable along the same path on all compute nodes. The default is to keep these output directories on the same NFS export as the SMRT Link installation, but optionally may be symbolically linked to a larger storage volume.
- **Analysis storage:** SMRT Analysis job output directory storage will approximately double the per SMRT Cell storage requirement. The amount of job storage required will depend on your utilization and analyses used.
  - For the **Revio** system, the sequencing data storage required is up to 78TB/year, assuming approximately 60GB of HiFi data per SMRT Cell and utilization at 1,300 SMRT Cells per year.
  - For the **Vega** system, the sequencing data storage required is up to 6TB/year, assuming approximately 30GB of HiFi data per SMRT Cell and utilization at 200 SMRT Cells per year.
- The SMRT Analysis **database directory** is used to store database files and backups. The software accesses this directory through a symbolic link (`$SMRT_ROOT/userdata/db_datadir`) that points to the desired database directory location. The link can be modified by using the installation script. This symbolic link destination should be a local directory (not NFS) and be writable by `$SMRT_USER`. This directory should exist only on the SMRT Link install host.
- The SMRT Analysis **temporary directory** is used for fast I/O operations during run time. The software accesses this directory through a symbolic link (`$SMRT_ROOT/userdata/tmp_dir`) that points to the desired temporary directory location. The link can be modified manually or using the installation script. This symbolic link destination should be a **local** directory (**not** NFS), it must be writable by `$SMRT_USER`, and the link destination must exist (or be creatable) as an independent directory on both the head node and the compute nodes.

Installation/upgrade checklist

The following is a list of items you should have ready before starting a new installation or upgrading an existing installation. **Note**: Paths that include spaces are not supported.

- Full path to the `$SMRT_ROOT` directory.
- A service account (called the `$SMRT_USER` in this document) to install and run the web services.
- Full path to the installation root directory, used for the main installation root.
- Job Management System settings.
- Full path to a directory on the shared file system - the `jobs_root` directory.
- Full path to a directory on the local file system on each node - the `tmp_dir` directory.
- Full path to a directory on the local file system on the install node - the `db_datadir` directory.
- **(Optional)** LDAP settings. See "Configuring LDAP in Keycloak" for details.
- **(Optional)** SSL certificate for NGINX. See "SMRT Link and SSL certificate procedures" for details.

Installation instructions

The following are the steps for installing SMRT Link v25.3 or SMRT Link Lite v25.3 on a new system. (See Appendix for details.)

- To upgrade SMRT Link to v25.3 from a previous version, see "Upgrading SMRT Link" for details.

SMRT Link v25.3 and SMRT Link Lite v25.3 can be used with the following supported version of ICS:

- v13.3 for Revio systems
- v1.1 for Vega systems

SMRT Link installation options

The following table lists the types of SMRT Link installations and what they include:

	SMRT Link	SMRT Link Lite	SMRT Link Cloud	SMRT Tools
Sample setup	Y	Y	Y	**N**
Run design	Y	Y	Y	**N**
Run monitoring	Y	Y	Y	**N**
Push-button secondary analysis (SMRT Analysis)	Y	**N**	**N**	**N**
Command line tools	Y	Y	**N**	Y
API access	Y	Y	Y	**N**

For additional details on **SMRT Link Cloud** please visit the PacBio software downloads page here.

SMRT Tools are the command-line tools included with SMRT Link. These are developer tools for use by bioinformaticians working with secondary analysis results. See Installing SMRT Tools for more details.

Step	Installation summary - SMRT Link v25.3/SMRT Link Lite v25.3
1	**Download SMRT Link software:** Download and extract the SMRT Link software installer from here. (The same installer can install **both** SMRT Link and SMRT Link Lite.)
2	Log onto the SMRT Link Install Host (such as the hostname or IP address) as the SMRT Link Install User (such as `$SMRT_USER`.)

3	**Install SMRT Link:**
	`./smrtlink_<version number>.run --rootdir $SMRT_ROOT`
	
	The `$SMRT_ROOT` directory must **not** exist when the installer is invoked, as the installer will try to create it, and will abort the installation if an existing `$SMRT_ROOT` location is found.
	
	If a previous installation was canceled or otherwise failed, the installer can be invoked **without** extraction. Rerun using the `--no-extract` option:
	`./smrtlink_<version number>.run --rootdir $SMRT_ROOT --no-extract`
	
	Single node system configuration:
	For the single node configuration, the following settings are recommended: nproc=12, nchunks=1, nworkers=4
	
	Additionally, it is recommended to adjust the concurrent_job_limit in Step 9 of the SMRT Link installation process or manually edit the `$SMRT_ROOT/userdata/generated/config/cromwell.conf` file to ensure that the number of concurrently running jobs does not exceed the available memory on your single-node system
	
	Install SMRT Link Lite:
	`./smrtlink_<version number>.run --lite true --jmstype NONE --rootdir $SMRT_ROOT --nworkers 4`
	
	See Appendix for additional information and configuration options.

5	**Start SMRT Link services**:
	`$SMRT_ROOT/admin/bin/services-start`
	If you need the Keycloak Admin interface enabled on external port `9443`, use this command:
	`$SMRT_ROOT/admin/bin/services-start --enable-keycloak-console`

6	**(SMRT Link only) Run the Site Acceptance Test from the command line:** `$SMRT_ROOT/admin/bin/run-sat-services` Successful completion of `run-sat-services` indicates that the HPC configuration is functioning correctly. This creates a "PacBio Example SAT Job" analysis entry in the SMRT Analysis section of the SMRT Link GUI.
7	**(Optional) Clear the browser cache:** Recommended to ensure that default settings are properly loaded. 1. Open the Chrome Browser and choose **More Tools > Clear browsing data**, choose **All Time** from the **Time Range** control, then check **Cached images and files**. Click **Clear data**. Restart the browser application.
8	**(Optional) Configure LDAP and/or add local users:** See "Configuring LDAP in Keycloak", "Adding local users to SMRT Link using Keycloak" for details.
9	**(Optional) Configure SMRT Link/SMRT Link Lite to use a signed SSL certificate:** See "Installing an SSL certificate for NGINX" for details.
10	**(Optional) Change the admin and pbicsuser passwords:** We recommend that you change the `admin` and `pbicsuser` account passwords from the default values. See "Changing admin and pbicsuser passwords" for details.

Upgrade instructions

Supported upgrade path

- SMRT Link upgrades to v25.3 are supported from any v13.x, v25.1, or v25.2 releases.
- SMRT Link Lite upgrades to v25.3 are supported from any v13.x, v25.1, or v25.2 releases.
- **Note**: You can upgrade from SMRT Link v10.x, v11.x, or v12.0 to SMRT Link v25.3. However, you must migrate to the new API gateway when starting service using `$SMRT_ROOT/admin/bin/services-start ---migrate`
  The migration launches an interactive CLI tool after the server starts. Once migration is finished, SMRT Link automatically starts with the new API gateway in the future.
- SMRT Link v25.3/SMRT Link Lite v25.3 can be used with the following supported version of ICS:
  - v13.3 for Revio systems
  - v1.1 for Vega systems

Step	Upgrading SMRT Link/SMRT Link Lite
1	Download and extract the SMRT Link software installer from here. (The same installer can install **both** SMRT Link and SMRT Link Lite.)
2	Log onto the SMRT Link Install Host (such as the hostname or IP address) as the SMRT Link Install User (such as `$SMRT_USER`.)
3	**Stop the SMRT Link services:** `$SMRT_ROOT/admin/bin/services-stop` **Note**: Ensure that no active SMRT Link analysis jobs are running before stopping services.

4	**Upgrade SMRT Link by invoking the SMRT Link installer:**
	`./smrtlink_<version number>.run --rootdir $SMRT_ROOT --upgrade`
	Note: The `$SMRT_ROOT` directory must be an existing SMRT Link installation. Several validation steps will occur to ensure that a valid `$SMRT_ROOT` is being updated.
	Upgrade SMRT Link Lite:
	`./smrtlink_<version number>.run --rootdir $SMRT_ROOT --upgrade --lite true`
	If a previous upgrade was canceled or otherwise failed, the installer can be invoked without extraction. Rerun using the `--no-extract` option:
	`./smrtlink_<version number>.run --rootdir $SMRT_ROOT --upgrade --no-extract`
	See Appendix for additional information and configuration options.

5	**Start the SMRT Link services:** `$SMRT_ROOT/admin/bin/services-start`
6	**(SMRT Link only) Run the Site Acceptance Test from the command line:** `$SMRT_ROOT/admin/bin/run-sat-services` Successful completion of `run-sat-services` indicates that the HPC configuration is functioning correctly. This creates a "PacBio Example SAT Job" analysis entry in the SMRT Analysis section of the SMRT Link GUI.
7	**(Optional) Clear the browser cache:** This is a good troubleshooting step if needed. It ensures the any updated default settings are properly loaded. 1. Open the Chrome Browser and choose **More Tools > Clear browsing data**, choose **All Time** from the **Time Range** control, then check **Cached images and files**. Click **Clear data**. 2. Restart the browser.
8	**(Optional) Change the admin and instrument user passwords:** We recommend that you change the `admin` and `pbicsuser` account passwords from the default values. See "Changing admin and pbicsuser passwords" for details.

Installing only SMRT Tools

To install **only** command-line SMRT Tools, use the `--smrttools-only` switch when calling the installer, whether for a new installation or an upgrade. (This installs the same command-line tools as a full installation.) Examples:

```
./smrtlink-25.3.0.xxxxx.run --rootdir $SMRT_ROOT --smrttools-only
```

```
./smrtlink-25.3.0.xxxxx.run --rootdir $SMRT_ROOT --smrttools-only --upgrade
```

Available tools will be installed at `$SMRT_ROOT/smrtcmds/bin/`. For tool details please utilize the help function, `{tool} --help`, or reference PacBio GitHub for select tools.

Note: Using `--smrttools-only` will **only** unpack the command-line applications and will **not** run through the configuration prompts or provide the web services of a full SMRT Link installation.

Warning: Revio and Vega systems cannot communicate with a `--smrttools-only` installation.

Changing admin and pbinstrument passwords

The SMRT Link `admin` account has full access to SMRT Link, and is used to create users and grant users access.

SMRT Link comes with a default Instrument Control Software (ICS) user account (`pbinstrument`) which is used by the Revio and Vega systems to communicate with SMRT Link web services over a secure, encrypted connection. The `pbinstrument` account is required for instruments to communicate with SMRT Link (**Note**: the `pbinstrument` credentials can only be used to access SMRT Link resources – it is not an LDAP account or a local account on the Linux system).

The passwords for the `admin` and `pbinstrument` accounts are set to default values that are the same for all SMRT Link installations. Because the passwords can be used to access SMRT Link accounts and information, the passwords should be changed and only given to trusted users who require access.

To change the built-in account passwords for the new API gateway, use the following procedure while the server is running:

```
$SMRT_ROOT/admin/bin/set-keycloak-creds --user admin --password 'NEW-PASSWORD' --admin-password
```

```
'CURRENT-PASSWORD'
```

```
$SMRT_ROOT/smrtcmds/developer/bin/pbservice-instrument set-smrtlink-password --user admin --ask-pass
```

To verify the `admin` and `pbinstrument` passwords, use the following procedure:

```
$SMRT_ROOT/smrtcmds/bin/pbservice status --host localhost --user admin --ask-pass
```

```
$SMRT_ROOT/smrtcmds/bin/pbservice status --host localhost --user pbinstrument --ask-pass
```

The `pbservice` status information should display, before exiting with an exit status of `0` indicating success.

Note: If the Keycloak Admin interface on HTTPS port `9443` is enabled, you can use it to change the admin password. (Unlike in previous versions of SMRT Link, changing the `admin` account password or even the user name with the user management interface now works correctly.)

Enabling the Keycloak admin console

If you need a graphical interface to administer user authorization functions, the Keycloak software that is included in SMRT Link is available. In SMRT Link 25.3 the port on which this GUI runs is closed by default for maximum security, but it can be enabled at start by adding an argument:

```
$SMRT_ROOT/admin/bin/services-start --enable-keycloak-console
```

Alternately, you can toggle the admin interface while the server is running:

```
$SMRT_ROOT/admin/bin/restart-gui --enable-keycloak-console
```

```
$SMRT_ROOT/admin/bin/restart-gui --disable-keycloak-console
```

Since this only requires restarting a single component, it will only interrupt external connections for a few seconds at most. We recommend leaving the console disabled when you are not actively managing server access.

LDAP integration

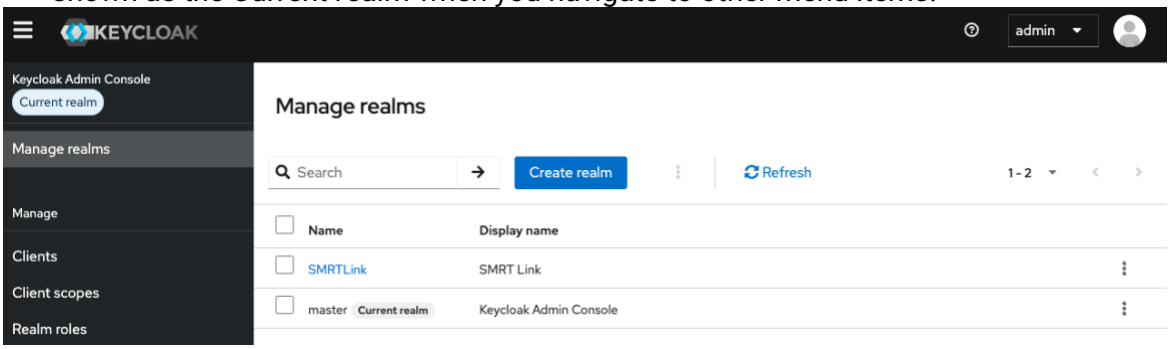
SMRT Link supports integration with LDAP for user login authentication, as well as using local Keycloak users that exist only within SMRT Link.
If you are interested in configuring SMRT Link integration with your organization's LDAP, PacBio recommends that you consult your LDAP administrator to help determine the correct LDAP settings. Note: Existing LDAP configurations are automatically migrated during upgrade.

Configuring LDAP in Keycloak

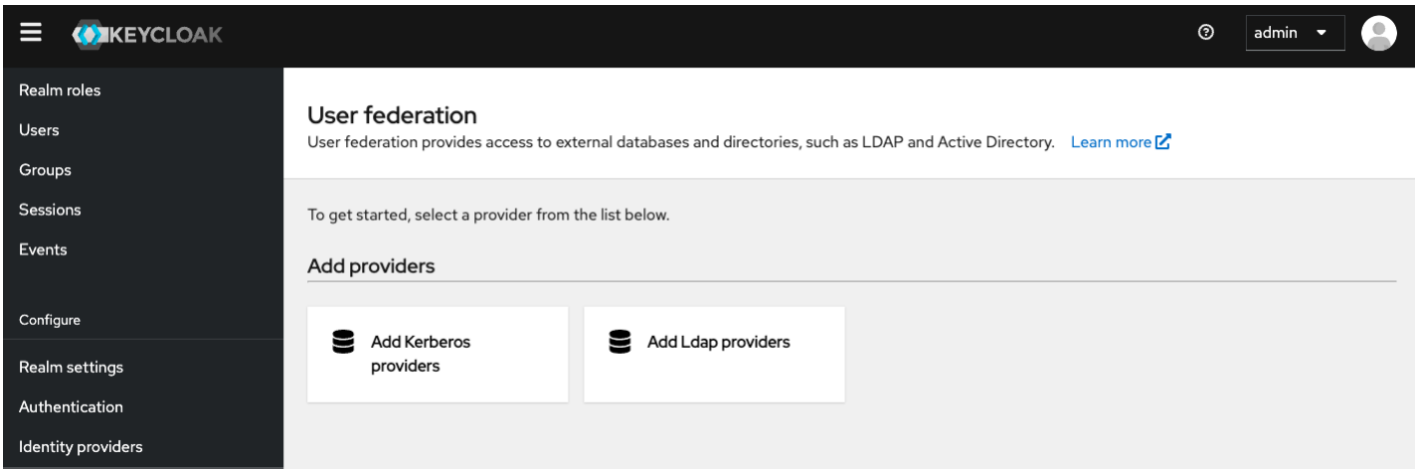
- LDAP is configured after SMRT Link v25.3 is installed, using the **Keycloak** authentication server software, as shown below.
- SMRT Link must first synchronize with your organization's LDAP objects before any directory accounts can be enabled and given a role to facilitate SMRT Link access.

1. Enter the following in your browser: `https://<hostname>:9443/admin/` where `<hostname>` is the host where SMRT Link is installed. (The Keycloak console must be enabled, as shown above.)
2. Login using `admin/admin` (unless you have changed the password).

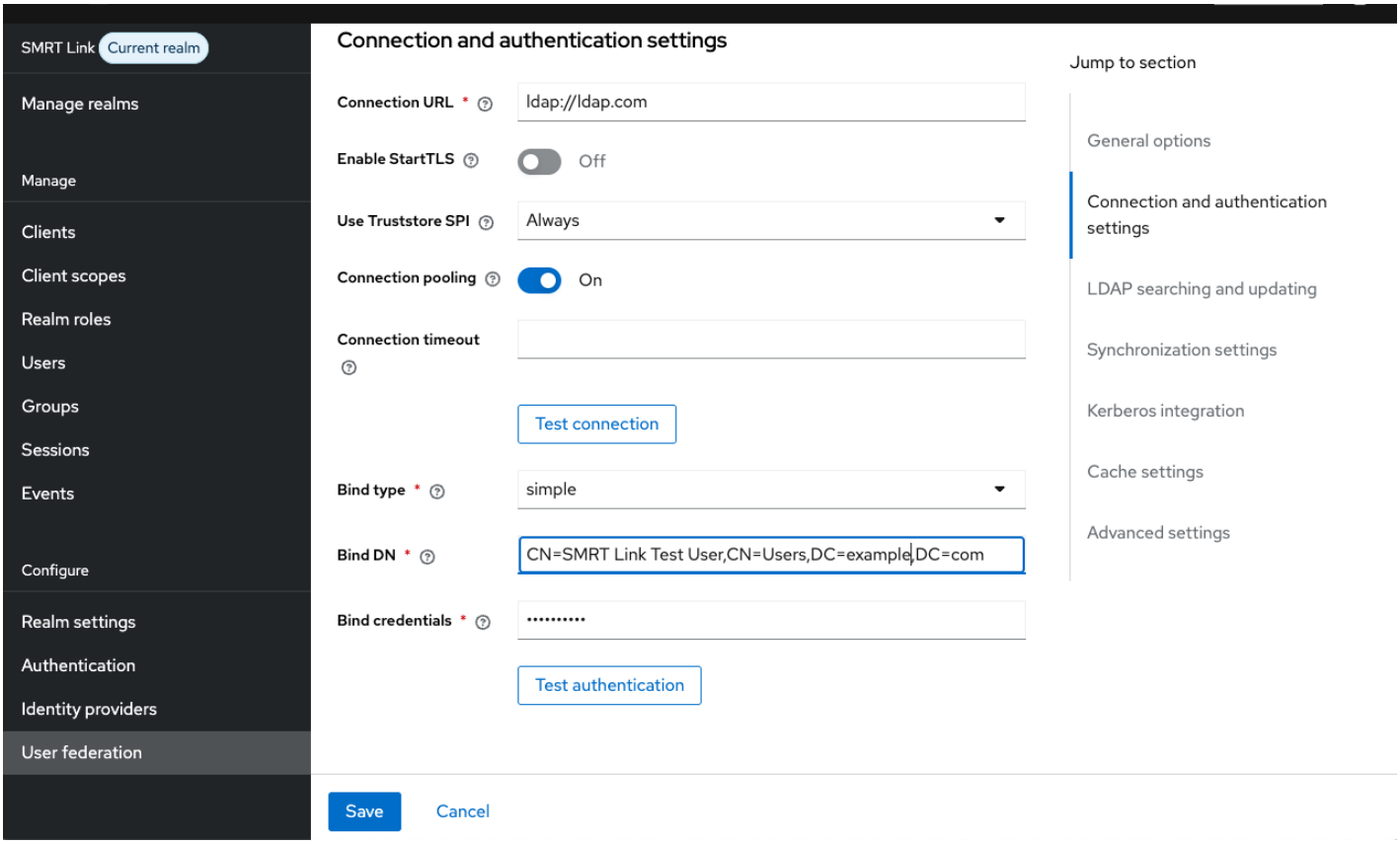
3. Click Manage realm and change the realm to SMRT Link by clicking "SMRTLink". SMRT Link will now be shown as the Current realm when you navigate to other menu items.



4. Under **Configure** on the left-hand side panel, click **User Federation** and click “Add Ldap providers”



5. Enter the required fields (and any others necessary for your LDAP server) and verify that you can connect to the server using the **Test connection** and **Test authentication** buttons. **Edit mode** should be READ_ONLY for LDAP searching and updating.



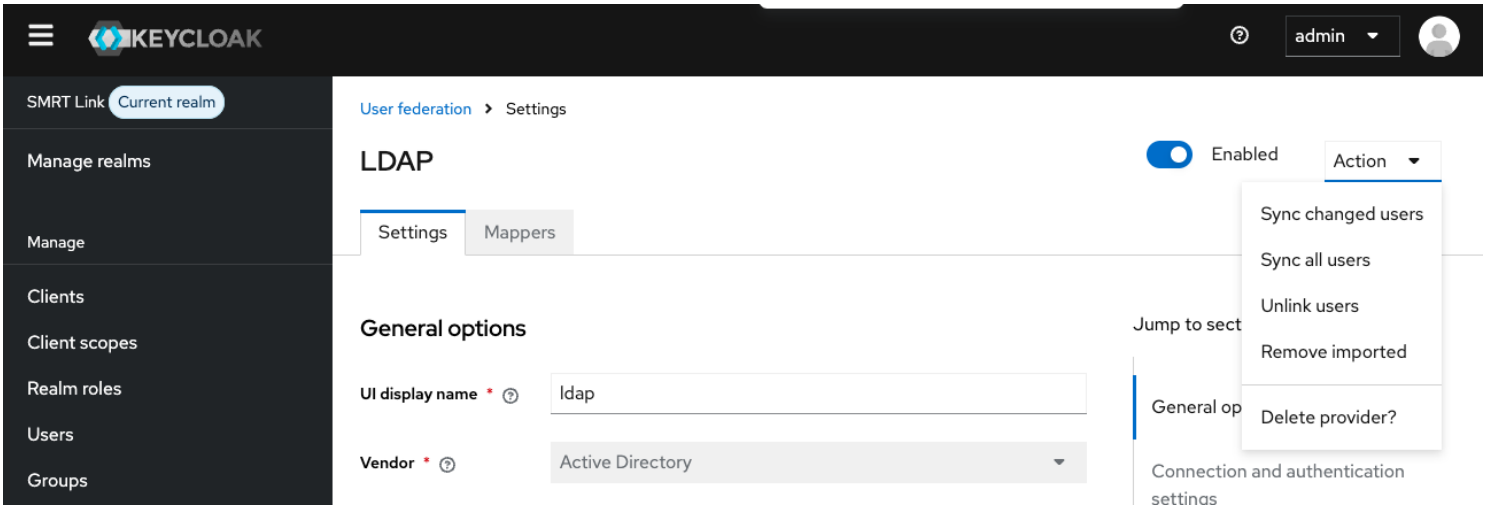
The following fields are required (**Note**: Values provided in the example above are listed below for clarity. Actual values should be provided by your LDAP administrator):

- Username LDAP attribute: `uid` (if you are using Active Directory, the most likely value is `sAMAccountName`)
- RDN LDAP attribute: `uid` (usually the same as the Username LDAP Attribute)
- UUID LDAP attribute: `entryUUID`
- User Object Classes: `person, organizationalPerson,user`
- Connection URL: `ldap://ldap.university.edu`
- Users DN: `CN=users,DC=university,DC=edu`
- (**Optional**) User LDAP Filter: `(objectClass=person)`
- **(Optional)** Edit mode: `READ_ONLY`

If `Bind Type` is `simple`, you also need to enter credentials for accessing the directory:

- Bind DN: `CN=ldapadmin,CN=users,DC=university,DC=edu.`
  This is the user account that is used to authenticate to the LDAP environment.
- Bind Credential: `<password>`

6. When you are finished click **Save**.
7. After you save the LDAP configuration, Click the Action drop down menu on the right and select **Sync all users** to import all users to the Keycloak database without assigning them SMRT Link roles.



8. Enable SMRT Link users individually as described in the next section.

For more information on LDAP, consult the following web pages:
https://en.wikipedia.org/wiki/Lightweight_Directory_Access_Protocol
https://en.wikipedia.org/wiki/LDAP_Data_Interchange_Format
https://msdn.microsoft.com/en-us/library/ms677605%28v=vs.85%29.aspx

Problems with the LDAP server may be debugged by looking at the log file located here:

`$SMRT_ROOT/userdata/log/smrtlink-analysisservices-gui/keycloak.stdout`

Note: If LDAPS needs to be used, the appropriate SSL certificate needs to be installed in a format understood by Keycloak. Use `keytool` to add the LDAPS X.509-formatted public certificate to a JKS file named `keycloak-truststore.jks`, set the passphrase to `password1`, and enter `yes` to force trust when prompted. To install the keystore, simply copy it to this location:

`$SMRT_ROOT/userdata/config/security/keycloak-truststore.jks`

Start the SMRT Link services, and in step 5 of the LDAP Integration instructions above, change the Connection URL to use an `ldaps:// URI` format, and, if necessary, adjust the port number. (**Note**: By default, LDAP uses TCP port `389` and LDAPS uses TCP port `636`).

SMRT Link user roles

SMRT Link supports three user roles: **Admin**, **Lab Tech**, and **Bioinformatician**. Roles define which SMRT Link modules a user can access. The following table lists the privileges associated with the three user roles: PacBio recommends the following role assignments:

Tasks/privileges	Admin	Lab Tech	Bioinformatician
Add/delete SMRT Link users	Y	N	N
Assign roles to SMRT Link users	Y	N	N
Update SMRT Link software	Y	N	N

Add/update instruments	Y	N	N
Access **Instruments** module	Y	Y	N
Access **Sample Setup** module	Y	Y	N
Access **Runs** module	Y	Y	N
Access **Data Management** module	Y	Y	Y
Access **SMRT Analysis** module	Y	Y	Y

- Assign at least one user per site to the **Admin** role. That individual is responsible for enabling and disabling SMRT Link users, as well as specifying their roles and adding/removing associated Revio instruments. The **Admin** can also access all SMRT Link modules, as well as every file in the system. (**Note**: SMRT Link supports multiple users with the **Admin** role per site.)
- Assign users who work in the lab preparing samples and performing runs the **Lab Tech** role. **Lab Tech** can also access all SMRT Link modules.
- Assign users who work **only** on data analysis the **Bioinformatician** role. **Bioinformatician** can only access the Instruments, Data Management and SMRT Analysis modules; this is the lowest access level.

Note: The Admin role only allows a user account to administer the configuration options available through the SMRT Link browser UI. It does not provide access to the Keycloak management interface, which is intentionally restricted to the built-in admin user only.

Adding SMRT Link users via LDAP integration and assigning user roles

- To enable users via LDAP integration, you must first configure LDAP before you can manage users and assign SMRT Link roles to users.
- After LDAP is configured, if you do **not** assign a SMRT Link role to a user, that user will **not** be able to login to SMRT Link.

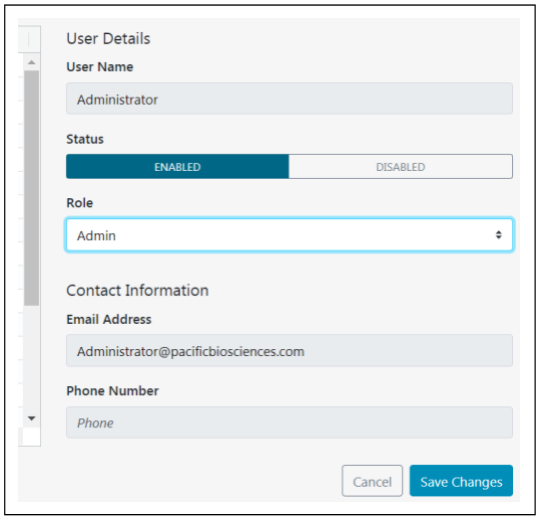
1. Access **SMRT Link**: Enter `https://<hostname>:8243/sl/home`, where <`hostname`> is the host where SMRT Link is installed.
2. Choose **Settings > User Management** at the top of the page.
3. There are two ways to find users:

- To display all SMRT Link users: Click Display all Enabled Users.
- **To find a specific user**: Enter a user name, or partial name and click **Search By Name**.

4. Click the desired user. If the Status is **Enabled**, the user has access to SMRT Link; **Disabled** means the user **cannot** access SMRT Link.

- To **add** a SMRT Link user: Click the **Enabled** button, then assign a role. (See Step 5.)
- To **disable** a SMRT Link user: Click the **Disabled** button.

5. Click the **Role** field and select one of the three roles. (A **blank** role means that this user **cannot** access SMRT Link.)
6. Click **Save Changes**. The user now has access to SMRT Link, based on the role just assigned.

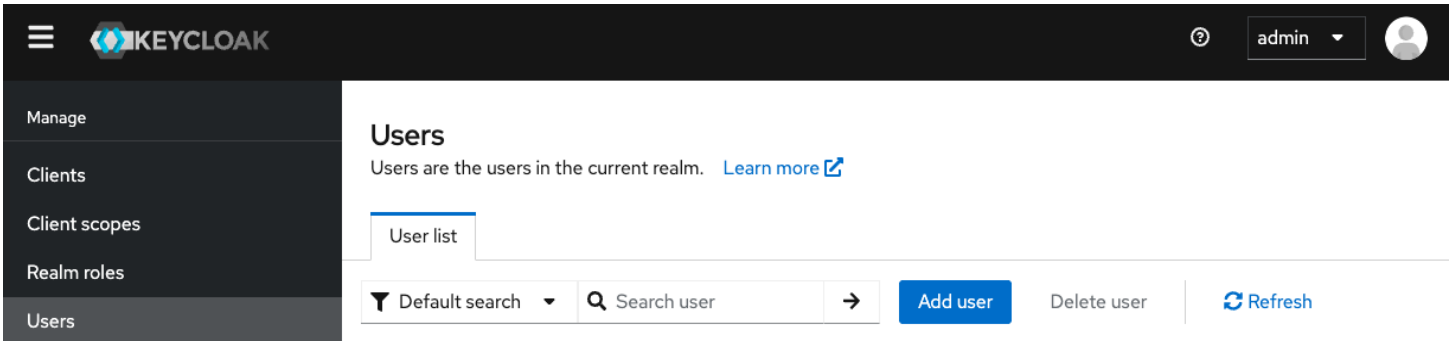


Adding local users to SMRT Link using Keycloak

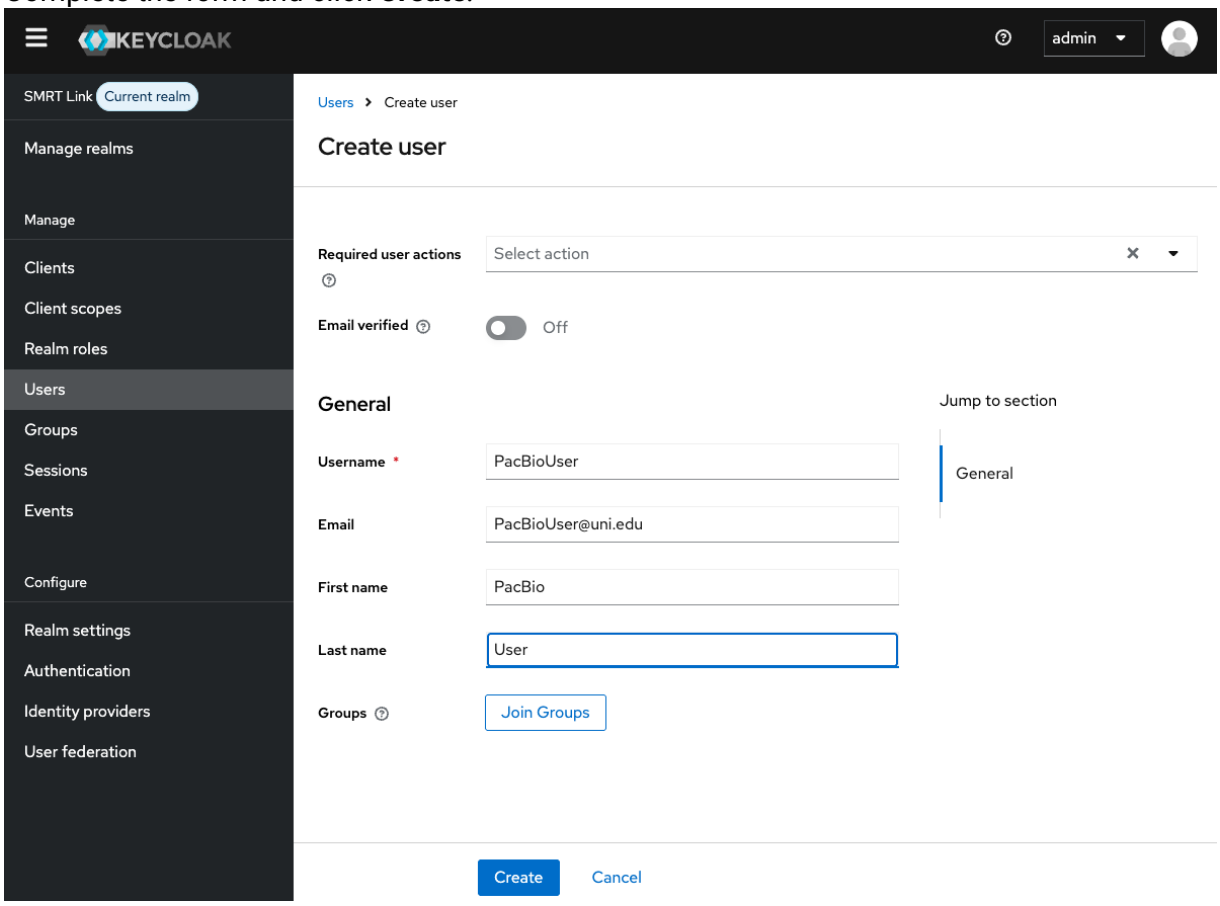
SMRT Link is designed to integrate with an LDAP server to provide user account information, but it is also possible to add **local** user accounts using the Keycloak server that handles authentication for the API gateway.

To add a local account:

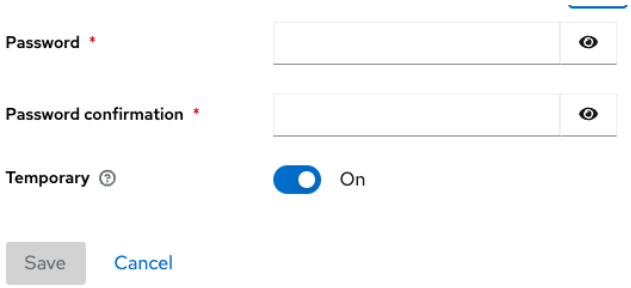
1. Access the Keycloak Admin interface at `https://<servername>:9443/admin` and log in with the SMRT Link built-in admin account credentials (`admin/admin` by default.)
2. On the left-hand menu, under **Manage**, click **Users**.
3. Click the **Add user** button on the right-hand side of the screen.



4. Complete the form and click **Create**.



5. In the newly added user page, click **Credentials**, and click Set password. If you are issuing a temporary password that the user needs to change on first login, make sure the **Temporary** toggle is **ON**. The section below covers password changes.

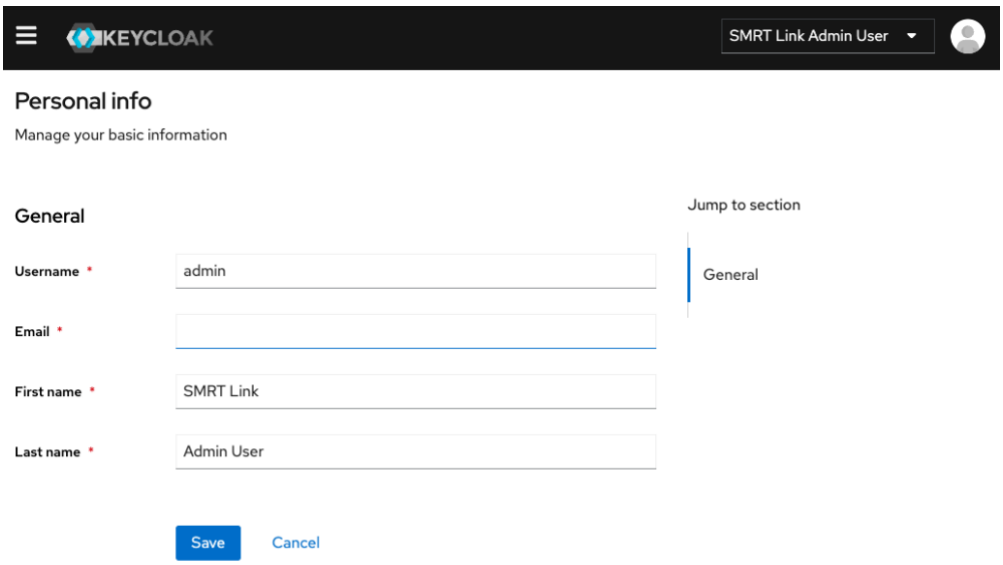


To change a temporary password:

1. When a new local user attempts to log in to SMRT Link with a temporary password, the login will fail with the message “Account is not fully set up”, and a button displays to open the Keycloak user console.

2. Log in to Keycloak with the same credentials. The Keycloak Admin interface will prompt the user to enter a new password.

3. Once the password has been changed, return to the SMRT Link login screen and enter the new password.
4. Local users may change their passwords again by navigating directly to the Keycloak user account page at `https://<hostname>:9443/realms/SMRTLink/account/#/`.



SMRT Link and SSL certificate procedures

SMRT Link v25.3 uses SSL (Secure Sockets Layer) to enable access via HTTPS (HTTP over SSL), so that your SMRT Link logins and data are encrypted during transport to and from SMRT Link. SMRT Link includes an authentication server (Keycloak), which can be configured to integrate with your LDAP/AD servers and enable user authentication using your organizations' user name and password. To ensure a secure connection between the SMRT Link server and your browser, a domain-specific SSL certificate may be installed **after** completing SMRT Link installation.

It is important to note that PacBio will **not** provide a CA-signed SSL certificate. However, once your site has obtained a CA-signed SSL certificate, PacBio's tools can be used to install it for use with SMRT Link web services. (**Note**: PacBio recommends that you consult your IT administrator about obtaining an SSL certificate.) You will need a certificate issued by a certificate authority (CA). PacBio has tested SMRT Link with certificates from the following certificate vendors: VeriSign, Thawte and DigiCert.

If your site does **not** provide an SSL certificate, SMRT Link v25.3 will use a PacBio self-signed SSL certificate. If you use the self-signed SSL certificate, **each** user will need to accept the browser warnings related to access in an insecure environment. You can also have your IT administrator configure desktops to **always trust** the provided self-signed certificate. Note that SMRT Link is installed within your organization's secure network, behind your organization's firewall.

See "Using SMRT Link with a PacBio self-signed SSL certificate" for details on how to handle the security warnings when accessing SMRT Link.

Use the following procedures **only** if your site provides an SSL certificate. These procedures are **not** applicable if you are using PacBio's self-signed SSL certificate.

Installing an SSL certificate for NGINX

In the new API gateway, SSL transport is handled by the NGINX web server, which uses a simpler configuration consisting of a plain-text certificate and private key. By default, SMRT Link will generate a self-signed certificate and key the first time you start the new API gateway:

```
$SMRT_ROOT/userdata/config/security/pb-smrtlink-default.crt
$SMRT_ROOT/userdata/config/security/pb-smrtlink-default.key
```

To install a custom certificate for NGINX

1. Stop SMRT Link services:

   ```
   $SMRT_ROOT/admin/bin/services-stop
   ```

2. Copy the certificate and private key files to these paths:

   ```
   $SMRT_ROOT/userdata/config/security/smrtlink-site.crt
   $SMRT_ROOT/userdata/config/security/smrtlink-site.key
   ```

3. Start SMRT Link services:

   ```
   $SMRT_ROOT/admin/bin/services-start
   ```

Restoring the default self-signed SSL certificate

It may sometimes be necessary to uninstall the user-provided SSL certificate and restore the default certificate. This requires the following steps.

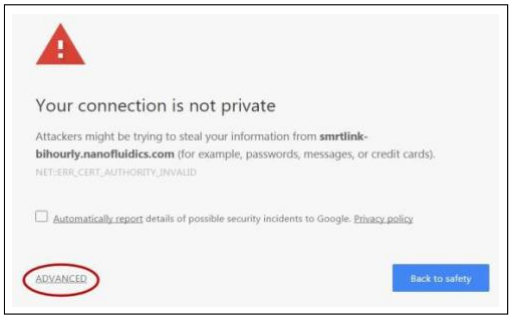
```
$SMRT_ROOT/admin/bin/services-stop
#remove or rename site certificates
$SMRT_ROOT/admin/bin/services-start
```

Using SMRT Link with a PacBio self-signed SSL certificate

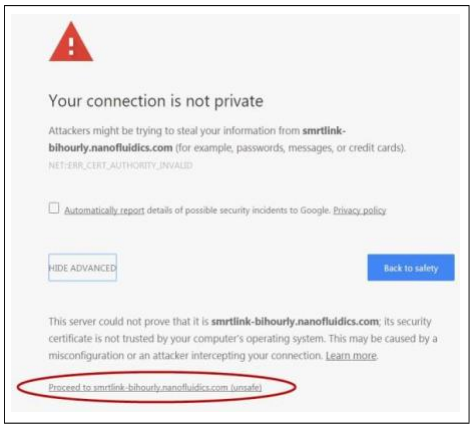
SMRT Link v25.3 uses self-signed SSL certificate generated by the installer. If your site does **not** have a signed SSL certificate **and** you use the self-signed SSL certificate, **each** user will need to accept the browser warnings related to access in an insecure environment. You can also have your IT administrator configure desktops to **always trust** the provided self-signed certificate. Note that SMRT Link should be installed within your organization's secure network, **behind** your organization's firewall.

Security messages display when users try to login to SMRT Link for the **first time** using the Chrome browser. These messages may also display **other times** when accessing SMRT Link. **Each** SMRT Link user in your organization should address these browser warnings following the procedure below.

1. The first time you start SMRT Link after installation, you see the following text. Click the **Advanced** link.



2. Click the **Proceed...** link. (You may need to scroll down.)



3. Close the window by clicking the **Close** box in the corner.

4. The **Login** dialog displays, where you enter the User Name and Password. The next time you access SMRT Link, the Login dialog displays **directly**.

Federated Single Sign-On (SSO) configuration

SMRT Link v25.3 includes built-in support for SSO via SAML 2.0 identity providers (e.g., Okta, Auth0, Keycloak). To configure SSO, the following three steps need to be completed sequentially.

1. Enable SMRT Link to use SSO
2. Create a SMRT Link SSO application
3. Configure Keycloak

Prerequisites

- A static, fully-qualified DNS name for your SMRT Link server (e.g., smrtlink.university.edu). Referred to as `{dnsName}` throughout this section.
- Ports 8243 and 9443 open to the local network on the SMRT Link server
- An alias for your provider (e.g., okta, auth0). Referred to as `{provider}` throughout this section.

1. Enable SMRT Link to use SSO

1. Stop SMRT Link services:
   ```
   $SMRT_ROOT/admin/bin/services-stop
   ```
2. Configure the SMRT Link software to enable SSO login
   ```
   $SMRT_ROOT/admin/bin/smrt_reconfig --batch --enable-sso true
   ```
3. Restart the server with the Keycloak admin console enabled
   ```
   $SMRT_ROOT/admin/bin/services-start --enable-keycloak-console
   ```
   The following message will be printed in the console:
   ```
   Keycloak admin console is now available and listening on port 9443.
   ```

To disable SSO:

```
$SMRT_ROOT/admin/bin/smrt_reconfig --batch --enable-sso false
```

Note: For security, we recommended disabling the Keycloak console after use. See Enabling the Keycloak admin console.

2. Create a SMRT Link SSO application

The LDAP/SSO IT administrator must create a new SAML 2.0 application for SMRT Link in accordance with your institution's policies. The SAML configuration should reference the Keycloak endpoint URL on port 9443 and the SMRT Link application URL on port 8243.

There are two basic steps to set up SMRT Link SSO in your SSO provider's portal:

1. Create a new application in your SSO provider's portal.
2. Download the generated configuration metadata XML.

To configure a new application, you will minimally need:

- The SAML endpoint:
  `https://{dnsName}:9443/realms/SMRTLink/broker/{provider}/endpoint`
- The default application page for SMRT Link:
  `https://{dnsName}:8243/sl/instruments`

Settings and fields may vary based on SSO provider and institutional policy. Following are select settings for Okta and Auth0 SSO providers. Depending on the network or security policies, the application may need to be explicitly enabled per-user.

Example settings for Okta

- Single Sign On URL: `https://{dnsName}:9443/realms/SMRTLink/broker/{provider}/endpoint`
- Recipient URL: `https://{dnsName}:9443/realms/SMRTLink/broker/{provider}/endpoint`
- Destination URL: `https://{dnsName}:9443/realms/SMRTLink/broker/{provider}/endpoint`
- Audience Restriction: `https://{dnsName}:9443/realms/SMRTLink/`
- Default Relay State: `https://{dnsName}:8243/sl/instruments`

Example settings for Auth0

- Allowed Callback URL:
  `https://{dnsName}:9443/realms/SMRTLink/broker/{provider}/endpoint`
- Addons: SAML2
  - Addons Application Callback URL:
    `https://{dnsName}:9443/realms/SMRTLink/broker/{provider}/endpoint`
  - Addons SAML2 Settings (copy and edit settings text block below):

```
{
  "audience": "https://{dnsName}:9443/realms/SMRTLink/broker/{provider}/endpoint",
  "mappings": {
    "email": "http://schemas.xmlsoap.org/ws/2005/05/identity/claims/emailaddress",
    "given_name": "http://schemas.xmlsoap.org/ws/2005/05/identity/claims/givenname",
    "family_name": "http://schemas.xmlsoap.org/ws/2005/05/identity/claims/surname"
  },
  "nameIdentifierFormat": "urn:oasis:names:tc:SAML:2.0:nameid-format:persistent"
}
```

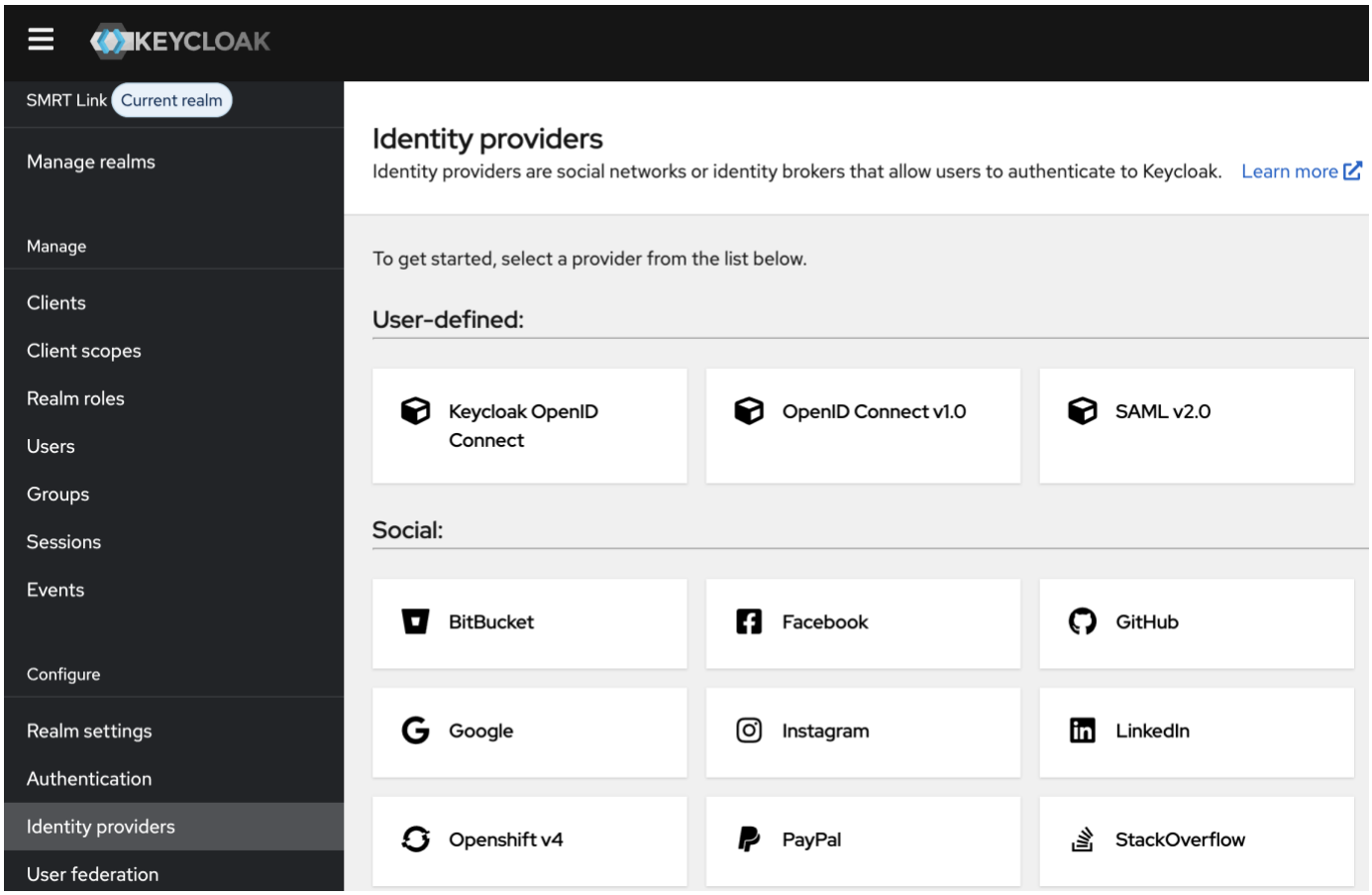
3. Configure Keycloak

The last step in setting up SSO for SMRT Link is configuring Keycloak. The bundled Keycloak server in SMRT Link is pre-configured with all settings required for SSO except for the identity provider itself, which is site-specific.

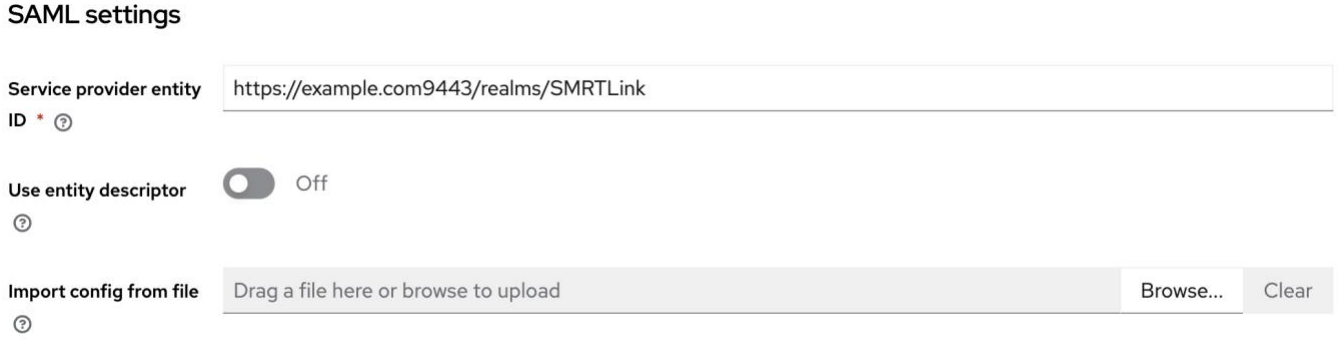
Before getting started, please ensure the following:

- SSO has been enabled (see Configure SMRT Link to use SSO).
- SAML metdata XML has been obtained (see Create a SMRT Link application)

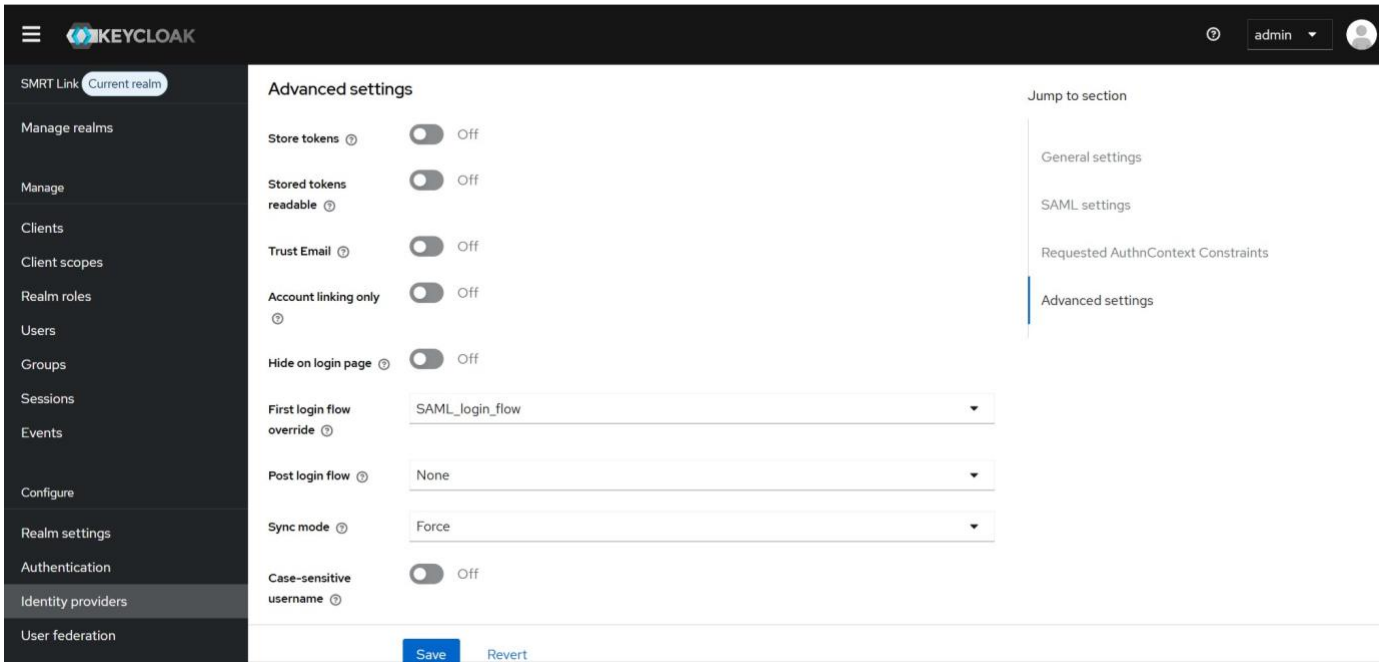
1. If not enabled already, enable Keycloak
   `$SMRT_ROOT/admin/bin/restart-gui --enable-keycloak-console`
2. Login into the Keycloak Admin consol at `https://{dnsName}:9443/admin/`
3. Click on the **Manage realms** tab on the left-hand menu and click **SMRTLink** to change the realm to SMRT Link (See Configuring LDAP in Keycloak for more detailed instructions)
4. Click on the **Identity providers** tab on the left-hand menu and select button labeled **SAML 2.0**. If you already have a provider configured the screen appearance may differ.



5. Change the **Alias** field to the value used to configure the SAML provider, e.g. `okta`. We recommend also setting the **Display name** field to a human-readable value (e.g. “PacBio Okta”), since this will appear on a button in the GUI.
6. Set **Use entity descriptor** to **Off** and upload your metadata XML in the field labeled **Import config from file** to auto populate configuration fields.



7. Change the setting **Want Assertions signed** to **On**.
8. Save the provider configuration.
9. In the updated provider configuration interface, find the setting labeled **First login flow override** in the updated form, and set it to `SAML_login_flow`, then save again. This specifies that SSO users will be added to the Keycloak database the first time they successfully sign on or linked to existing database entries if returning.



10. Select **Mappers** tab and create a new mapper named `add_role_mapper`, with **Mapper type** set to **Hardcoded Role**. We recommend that **PbLabTech** as the default role by First select **Filter by realm roles** in the **Assign roles to role** selection window. This will automatically grant access to SMRT Link as a lab tech user, with access to all modules but not administrative functions.
11. Test the configuration by navigating to the SMRT Link home page at `https://{dnsName}:8243/sl` and confirm that the SSO button is available and that sign on is successful.

Security

The most important thing that SMRT Link administrators can do to minimize their attack surface is to place the server on a private network behind institutional firewalls. We also recommend regularly inspecting the following logs which will record every HTTPS request and point of origin on port 9443.

- Keycloak log `$SMRT_ROOT/userdata/log/smrtlink-analysisservices-gui/keycloak.stdout`
- NGINX access log at `$SMRT_ROOT/userdata/log/smrtlink-analysisservices-gui/nginx/`

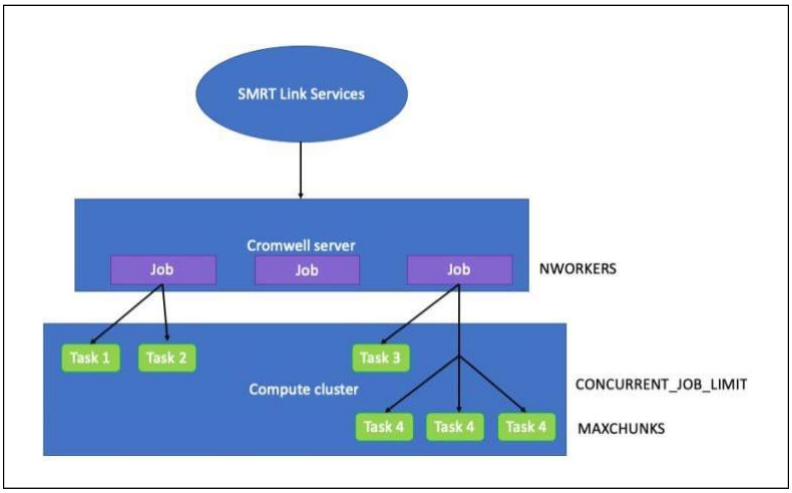
Migrating from LDAP/AD
Mixing LDAP and SSO configurations with overlapping user accounts may lead to unpredictable behavior and is not recommended.

For sites using Keycloak with an LDAP(S)-compatible directory service (including Active Directory), adding an SSO configuration should not disrupt the experience of existing authorized users, except for the change in login behavior. After configuring SSO, it is possible to have separate user accounts for LDAP and SSO users. For example, a username in the database might be "pbio" while the SSO username could be "pbio@company.com." This difference will be visible in the SMRT Link GUI for record types containing a `createdBy` field. We recommend that admins manually delete the old LDAP user accounts once users confirm they can access via SSO. Deleting these accounts will not affect existing records or user history in SMRT Link, but it will disable API access for the user through tools like `pbservice`.

Appendix

SMRT Link configuration terminology

A continuously running Cromwell server is launched at the same time as SMRT Link services, which executes all jobs directly without spawning new processes. Several user-configurable settings control the use of compute resources by `Cromwell`. A representation of the SMRT Link services hierarchy is shown below.



NWORKERS: A SMRT Link services setting that specifies the maximum number of simultaneous analysis jobs (or workflows, as `Cromwell` refers to them) that may be run.

CONCURRENT_JOB_LIMIT: A `Cromwell` configuration setting that limits the total number of job submissions to a specific backend, across all running workflows.

MAXCHUNKS: A `Cromwell` workflow that limits the maximum number of pieces a large Data Set may be broken into for parallelized analysis.

NPROC (Not shown in diagram): A `Cromwell` workflow setting that limits the maximum number of slots that any single JMS cluster submission may request.

Distributed computing setup

Running SMRT Link with SMRT Analysis requires the SLURM Job Management System (JMS). PBS and LSF can be used, but are not officially supported and will require additional configuration.

Because Slurm is required for SMRT Analysis it may be used to dispatch jobs to a distributed compute environment. If no JMS is specified, the system will run in non-distributed mode, and all compute jobs will be run locally on the install host.

Available Job Management Systems are detected from the PATH environment variable but may also be selected manually.

For more information on customizing all the submissions to the JMS, see the comments in the file `$SMRT_ROOT/userdata/user_jmsenv/user.jmsenv.ish`. Note that changes to this file will apply to every job submitted to the cluster.

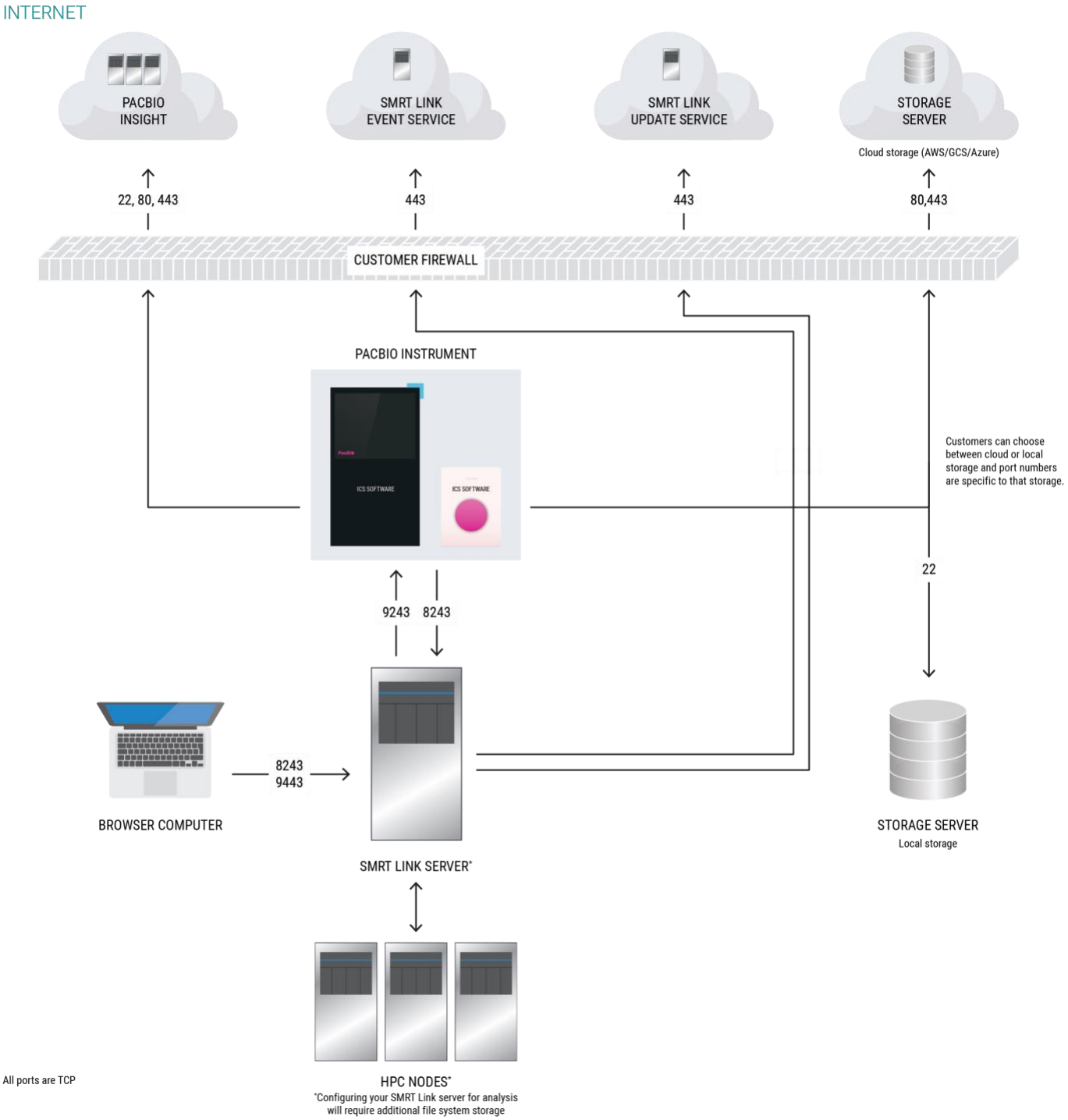
Revio and Vega system and SMRT Link, or SMRT Link Lite, network ports and protocols

Source	Destination	Port/Protocol	Description
Revio and Vega system	SecureLink Servers	22/tcp, 80/tcp, or 443/tcp	Communication for remote support (PacBio Insight)
Revio and Vega system	Storage (Cloud or local)	SSH: 22/tcp, Cloud: 80/tcp or 443/tcp depending on protocol	Data transfer from instrument to customer storage
Revio and Vega system	Customer or external NTP servers	123/udp	Used for updating machine time. Defaults to pool.ntp.org
Revio and Vega system	Customer server	53/udp or 53/tcp	Nameservers
Revio and Vega system	SMRT Link server	8243/tcp	Communication from instrument to SMRT Link
SMRT Link server	Revio and Vega system	9243/tcp	Communication from SMRT Link to instrument
Customer laptop/ desktop PC	SMRT Link server	8243/tcp	SMRT Link web services and GUI https
Customer laptop/ desktop PC	SMRT Link server	9443/tcp	Optional SMRT Link Administration https (API Management Interface)
SMRT Link server	Shared Network File System (NFS) [a]	NFS ports (may vary depending on configuration)	Shared file system (NFS) storage for analysis data
SMRT Link server	PacBio Event server (https://smrtlink-eve.pacbcloud.com:443)	443/tcp	Optional reporting of server metrics to PacBio Tech Support
SMRT Link server	PacBio Update server (https://smrtlink-update.pacbcloud.com:8084)	443/tcp	Downloading Chemistry Updates
HPC nodes	Shared Network File System (NFS) storage[a]	NFS ports (may vary depending on configuration)	Shared file system (NFS) storage for analysis data

a. Network file system requirements: If used, NFS mounts to the input and output locations; HPC compute nodes must be able to write back to the NFS; Additional file system storage may be required if using SMRT Link for analysis. This approximately doubles the storage requirement.

SMRT Link Server Network diagram

Vega and SMRT Link, including SMRT Link Lite, network diagram



Security

General security

- PacBio recommends that you install the SMRT Link server on networks that are only accessible to trusted users, and discourages installing SMRT Link on public networks.
- Do **not** install SMRT Link or run SMRT Link services as the `root` user.

SMRT Link v25.3 security

SMRT Link v25.3 restricts access to the web services API to clients running on `localhost` (such as the API gateway that handles authentication and permissions) or remotely using SSL encryption and password-based authentication.

Support for the WSO2 API Manager was deprecated in v12.0, and this API is no longer supported. New installations will automatically start the replacement API gateway. **Customers who are upgrading existing SMRT Link installations will need to migrate to the new API gateway**.

SMRT Link database backups

- SMRT Link v25.3 does not perform periodic database backups. A database backup is still automatically performed once, during installation or upgrade. Failure to back up the SMRT Link database on a regular schedule risks losing all records in SMRT Link (including users, Data Sets, analyses, barcodes, and references) if a file system or reconfiguration error occurs. The underlying sequencing or analysis files, such as BAM files, are **not** affected.
- We **strongly** recommend asking your local Linux system administrator to schedule regular weekly backups of the SMRT Link database using standard Linux utilities. A utility script to generate an appropriate `cron` server command was added at `$SMRT_ROOT/admin/bin/generate-cron-backup`.
- The `generate-cron-backup` script should be run after each upgrade.

Sending log files to Technical Support

Troubleshooting information can be sent to PacBio Technical Support multiple ways. If there is a connection to the PacBio Event Server, do the following:

- From the SMRT Link menu: About > Troubleshooting Information > Send.
- From a SMRT Link “Failed” analysis Results page: Click **Send Log Files**.

If there is connectivity to the PacBio Event Server, run the following command to generate the information and automatically send it to PacBio Technical Support:

```
$SMRT_ROOT/admin/bin/tsreport-install --bundle --upload
```

If there is **no** connectivity to the PacBio Event Server, run the following command to generate a .tgz file and email the file to `support@pacb.com` to file a case:

```
$SMRT_ROOT/admin/bin/tsreport-install --bundle
```

The generated file can be found here: `$SMRT_ROOT/userdata/tsreport/data/ts-install.tgz.`

Note: The SMRT Link logs archive bundle will be limited to logs from approximately the past 24 hours. Ensure the above `tsreport-install` options and SMRT Link menu's **Send** button are run within **one day** of experiencing the issue being addressed.

Changing usage tracking settings

When first logging in to the SMRT Link GUI after a successful installation or upgrade, users are prompted to notify PacBio of the upgrade/installation success and whether they wish to share SMRT Link analysis usage information with PacBio. We recommend accepting these conditions to better enable remote troubleshooting by PacBio support personnel. Once set, these settings may **only** be viewed and modified from the command line using the `accept-user-agreement` tool.

WARNING: To use the `accept-user-agreement` tool, services must be running:

```
$SMRT_ROOT/admin/bin/services-start
```

To set new settings, use the following command, specifying `true` or `false` for the options accordingly. For example:

```
$SMRT_ROOT/admin/bin/accept-user-agreement --install-metrics true --job-metrics
true
```

PacBio is notified of a successful installation or upgrade **immediately** if the install metrics setting is `true`. To view the current settings, run the command without any arguments:

```
$SMRT_ROOT/admin/bin/accept-user-agreement
```

Note: If `accept-user-agreement` is run without arguments and the settings have not been previously set (either in the GUI or on the command line), both the install and job metrics settings will automatically be set to `true` and PacBio will be immediately notified of the installation or upgrade.

Starting SMRT Link automatically on server boot

To start SMRT Link automatically when the server boots using `systemd`, refer to the template service file located here:

```
$SMRT_ROOT/admin/template/smrtlink.service.tmpl
```

Follow the instructions in the template comments to make site-specific modifications and install as a `system` service unit.