A Quick Guide for the pbdRPC Package

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Contents

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Warning:
This document is written to explain the main functions of **pbdRPC** (Chen 2017), version 0.1-1. Every effort will be made to ensure that future versions are consistent with these instructions, but features in later versions may not be explained in this document.

Information about the functionality of this package, and any changes in future versions can be found on website: "Programming with Big Data in R" (pbdR) at `http://r-pbd.org/` (Ostrouchov *et al.* 2012).

1. Introduction

This package, **pbdRPC** (Chen 2017), provides one high level function, `rpc()`, that can securely send commands to remote servers via `ssh` (OpenSSH) or `plink`/`plink.exe` (PuTTY). The high-level function is a very light yet secure implementation because the communications are encrypted, by default SSH version 2 using RSA key pairs, between a local client and remote servers. The high-level function is simply a wrapper of two low-level functions, `ssh()` and `plink()`. These functions can ask remote servers to execute commands without logging in the servers provided that an authentication is set properly.

Four RPC controls are provided by the package to simply the functions:

1. `.pbd_env$RPC.CT` is main RPC controls taking care several basic functionalities of three functions, `rpc()`, `ssh()`, and `plink()`.

2. `.pbd_env$RPC.LI` has information of login account for logging in the remote server include authentication using private keys. See Section 2 for details.

3. `.pbd_env$RPC.RR` has examples of executing multiple commands on a remote server which is an application related to an R package, **remoter** (Schmidt and Chen 2016b). See Section 3 for details.

4. `.pbd_env$RPC.CS` has examples of executing multiple commands on a **pbdCS** cluster which is an application related to an R package, **pbdCS** (Schmidt and Chen 2016a). See Section 4 for details.

Note that `.pbd_env` will be first generated when the library **pbdRPC** is loaded, then default objects `RPC.CT`, `RPC.LI`, `RPC.RR`, and `RPC.CS` will be generated.

In general, only `RPC.CT` and `RPC.LI` are required to be set by users according to their environment configurations. The `RPC.RR` and `RPC.Cs` are simple templates to show two pbdR applications. Users are welcomed to adopt those templates and to develop personal applications wherever automations can be benefit by remote procedure calls.

Most OSs (Linux, Solaris, Mac OSX) have the system command `ssh` (OpenSSH) installed, so the `ssh()` is a wrapper function to the system `ssh` command. For Windows, the `plink.exe`

(from PuTTY) will be compiled with **pbdRPC**, so the `plink()` is a wrapper function to the executable file, `plink.exe`. Note that for non-Windows system, the `plink` can be compiled as well.

1.1. Basic `ssh` and `rpc()`

Suppose a `sshd` is set and running correctly on a server running a Linux system at an ip address "192.168.56.101" and a port "22". Further, suppose an account called "snoweye" is created and a password for the account is set on the server.

From a terminal or a shell of non-Windows systems, one may use

Basic `ssh` in shell

```
$ ssh snoweye@192.168.56.101 'whoami'
```

to access the server and to ask the server to execute a command `whoami`. Typing the password for the login account may be needed. The command `whoami` is available on most Linux systems, it should return the command result, "snoweye", on the screen/stdout without logging in a shell environment on the server. In the same setup, the command `whoami` can be replaced by any other proper programs, shell scripts, or procedures. For Windows system, one may use `plink.exe` instead of `ssh` from a terminal `cmd.exe`. See Section 1.3 for details.

Within R, the next example will have the same results as the above shell command.

Basic `rpc()` in **pbdRPC** and R

```
> library(pbdRPC, quietly = TRUE)
>
> ### Alter login information as needed
> rpcopt_set(user = "snoweye", hostname = "192.168.56.101")
> rpc("whoami")
```

The command results may be captured by R as well.

Regardless the system, the high level function `rpc()` can unify the calls to either `ssh()` or `plink()` functions. One may use `ssh()` in non-Windows system, but use `plink()` in Windows system. The `rpc()` automatically detects the system first, then calls the corresponding function. Currently, no external `plink.exe` or `plink` is implemented even though it is possible. The details of `ssh()` and `plink()` are given in next.

1.2. Basic `ssh()`

Inside R and via **pbdRPC**, this can be done by

Basic `ssh()` in **pbdRPC** and R

```
> library(pbdRPC, quietly = TRUE)
> ssh("snoweye@192.168.56.101 'whoami'")
```

provided all other options (port, forwarding, etc) are set correctly. Note that the password for the account may be required when an authentication file (`id_rda`) is not available.

Note that multiple commands can be automatically given at once as shell commands under an shell prompt, such as "`;`", "`&&`", "`>`", "`<`", "`|`" or "`&`" etc. For example, the next will tell current id, date/time, and files.

Multiple commands to `ssh` in shell

```
$ ssh snoweye@192.168.56.101 'whoami;date;ls -a'
```

The multiple commands can be applied to `ssh()` and `plink()` as

Multipel commands to `ssh()` in **pbdRPC** and R

```
> library(pbdRPC, quietly = TRUE)
> ssh("snoweye@192.168.56.101 'whoami;date;ls -a'")
```

See Section 3 and `.pbd_env$RPC.RR` for more details.

1.3. Basic `plink.exe` and `plink()`

In Windows system and inside the `cmd.exe`, one may similarly use next

Basic `plink.exe` in `cmd.exe`

```
C:\> plink.exe snoweye@192.168.56.101 'whoami'
```

to access the server provided `plink.exe` is in the `PATH`.

Inside `RGui` and via **pbdRPC**, this can be done by

Basic `plink()` in **pbdRPC** and R

```
> library(pbdRPC, quietly = TRUE)
> plink("snoweye@192.168.56.101 'whoami'")
```

provided all other options (port, forwarding, etc) are set correctly. The multiple commands can be applied to `plink()` as well.

By default, the `plink()` will open an `cmd.exe` to execute the command `whoami` because the password input is not allowed inside `RGui`. When the authentication file (`id_rsa.ppk`) is available, one may want to disable the opening `cmd.exe` as in next.

Advance `plink()` in **pbdRPC** and R

```
> .pbd_env$RPC.CT$use.shell.exec <- FALSE
> ret <- plink("snoweye@192.168.56.101 'whoami'")
> print(ret)
```

Because the `shell.exec()` is disable, the `plink()` call may accept returns of the remote server and capture/save the returns in an R object, `ret`.

The `use.shell.exec` is for Windows system only and required to be `TRUE` when `RGui` is mainly used. The `plink()` in `RGui` may hang forever or crash when input/typing of a password or a passphrase is needed for logging in the server. `RGui` has different stdin and stdout than a usual terminal. The `use.shell.exec` can be switched to `FALSE` when the authentication is correct and no passphrase is needed, i.e. no stdin input/typing. However, `Rcmd` running within a `cmd.exe` may be OK with stdin input/typing when `use.shell.exec = FALSE`.

Other solutions to replace internal `plink.exe` of **pbdRPC** include:

- The `plink.exe` can be installed from the PuTTY as well.

- Windows PowerShell and git also provide `ssh.exe` but additional installation/configuration is unavoidable.

2. Handling Login Information

Suppose an Oracle VM VirtualBox runs Xubuntu 15.10 as the guest OS within a Windows 8 system as the host OS. The VM has an virtual network adaptor (host-only) with IP address `192.168.56.101`, so that one can login to the VM using either `telnet`, `plink`, or `ssh` from the Windows 8 system. Note that `telnet` and `ssh` uses ports 23 and 22 as default, respectively. Suppose further the login id is called "snoweye", then one may use the function `rpcopt_set()` to assign/overwrite the login information to `.pbd_env$RPC.LI` as in next.

Set login information

```
> ### Alter login information as needed
> rpcopt_set(user = "snoweye", hostname = "192.168.56.101", pport =
   "22")
```

In next, the basic login information `RPC.LI` describes that `rpc()` will

- use `ssh` (exec.type) to execute a command (given by `rpc()`, `ssh()`, or `plink()`)
- with `args` (additional arguments to `ssh` or `plink.exe`)
- and a `user` account (snoweye)
- login into a `hostname` (server ip = `192.168.56.101` or host name)
- from a `pport` (server port = 22), and
- may use authentication keys in `priv.key` or `priv.key.ppk`.

Basic `RPC.LI`

```
> .pbd_env$RPC.LI
$exec.type
[1] "ssh"

$args
[1] ""

$pport
[1] "22"

$user
[1] "snoweye"

$hostname
[1] "192.168.56.101"

$priv.key
```

```
[1] "~/.ssh/id_rsa"

$priv.key.ppk
[1] "./id_rsa.ppk"
```

Currently, the `exec.type` is only for non-Windows systems, and it will be ignored on Windows systems ("plink" will be used). Also, `ssh` uses "`-p`" (lower case) to input the server port argument. `plink.exe` uses "`-P`" (upper case) to input the server port argument. Therefore, the `args` should not include "`-p`" nor "`-P`" to avoid confusion in the unified function `rpc()`. Similarly, the "`-i`" may not be include in the `args` as well because additional authentication may be required.

The account may have the private key for authentication to avoid typing the login password for the user account. The private keys may be stored in files indicated by `prive.key` for `ssh()` or `prive.key.ppk` for `plink()`. When all setups are correct, command calls can be executed at the `hostname` (192.168.56.101) remotely. By default, the `prive.key.ppk` will be read from the current working directory (from `getwd()`) in Windows systems. In this case (`"./id_rsa.ppk"`), the file `C:/Users/login_account/Documents/id_rsa.ppk` is probably read for authentication.

To generate private and public keys is pretty standard for most Linux systems via the `ssh-keygen` command which will generate keys in OpenSSH format. One may use `puttygen` in Linux to convert OpenSSH format to PuTTY format for Windows. See Section 7.1 for the conversion from `id_rsa` to `id_rsa.ppk`. For Windows systems, one may also use `puttygen.exe` to obtain both keys.

3. An Application with remoter

The **remoter** (Schmidt and Chen 2016b) and **pbdZMQ** (Chen *et al.* 2015) provide client/server interface to control a remote R (e.g. running on a single server, Xubuntu, ip=192.168.56.101) from a local R (e.g. running on a single laptop, Windows 8). Combining with **pbdMPI** (Chen *et al.* 2012) and **pbdCS** (Schmidt and Chen 2016a), one may extent the remote R to the R clusters by running R's in a distributed/SPMD environment.

- See Schmidt *et al.* (2016) for an introduction of **remoter** and **pbdCS**.
- See `http://github.com/snoweye/user2016.demo` for a demo of both packages.
- See pbdR-Tech (`http://snoweye.github.io/pbdr/`) and HPSC (`http://snoweye.github.io/hpsc/`) websites for more applications of SPMD and how to utilize R in clusters (Chen and Ostrouchov 2012).

In a simplified scenario such as the setting in Section 2, one may use the following commands to "start", "check", and "kill" a remote R server under a shell environment provided `Rscript` is in `PATH` of the login server (pre-load or set by the `00_set_devel_R`).

remoter server at 192.168.56.101

```
$ source ~/work-my/00_set_devel_R
$ nohup Rscript -e 'remoter::server()' > .rrlog 2>&1 < /dev/null &
$ ps ax|grep '[r]emoter::server'
```

```
$ kill -9 $(ps ax|grep '[r]emoter::server'|awk '{print $1}')
```

In an well established server, one can use `ssh` or `plink.exe` to send those commands from a local laptop. Furthermore, one may also use **pbdRPC** directly within an R environment to send those commands. The example is in next.

Using **pbdRPC** to control **remoter**

```
> library(pbdRPC, quietly = TRUE)
>
> ### Alter login information as needed
> rpcopt_set(user = "snoweye", hostname = "192.168.56.101")
> .pbd_env$RPC.CT$use.shell.exec <- FALSE
>
> preload <- "source ~/work-my/00_set_devel_R; "
> start_rr(preload = preload)
character(0)
>
> library(remoter)
Loading required package: pbdZMQ

Attaching package: 'remoter'

The following object is masked from 'package:grDevices':

    dev.off

The following objects are masked from 'package:utils':

    ?, help

> client(addr = "192.168.56.101")
WARNING: server not secure; communications are not encrypted.

remoter> 1+1
[1] 2
remoter> q()
>
> check_rr()
[1] " 2014 ?        Sl     0:00
   /home/snoweye/work-my/local/R-devel/lib64/R/bin/exec/R --slave
   --no-restore -e remoter::server()"
> kill_rr()
character(0)
```

where `client()` is for connect to the remote R server started by `start_rr()`. Note that all commands in the above example were typed inside a local R in the local laptop. However, the computation `1+1` was done by a remote R on the server (192.168.56.101).

The `start_rr()`, `check_rr()`, and `kill_rr()` are all wrapper functions of `rpc()` to submit different commands stored in `.pbd_env$RPC.RR$start`, `.pbd_env$RPC.RR$check`, and `.pbd_env$RPC.RR$kill`, respectively. The tedious details of `RPC.RR` are in next which all can be simply sent by `rpc()` to execute on the server.

RPC.RR for controlling **remoter**

```
> .pbd_env$RPC.RR
$check
[1] "ps ax|grep '[r]emoter::server'"

$kill
[1] "kill -9 $(ps ax|grep '[r]emoter::server'|awk '{print $1}')"

$start
[1] "nohup Rscript -e 'remoter::server()' > .rrlog 2>&1 < /dev/null &"

$preload
[1] "source ~/work-my/00_set_devel_R; "
```

4. An Application with pbdCS

Similar to the **remoter**, the **pbdCS** (Schmidt and Chen 2016a) provides interactivity for clusters running R's via the **pbdMPI** (Chen *et al.* 2012) in SPMD computing framework (Ostrouchov *et al.* 2012; Chen and Ostrouchov 2012). See Schmidt *et al.* (2016) for an introduction of **remoter** and **pbdCS**, and see https://github.com/snoweye/user2016.demo for a demo of both packages.

In a simplified scenario such as the setting in Section 2, several pbdCS R's can run 4 instances on the server, Xubuntu, ip=192.168.56.101 as in the next.

pbdCS cluster with 4 R instances

```
$ source ~/work-my/00_set_devel_R
$ nohup mpiexec -np 4 Rscript -e 'pbdCS::pbdserver()' > .cclog 2>&1 <
   /dev/null &
$ ps ax|grep '[p]bdCS::pbdserver'
$ kill -9 $(ps ax|grep '[p]bdCS::pbdserver'|awk '{print $1}')
```

The example above is very similar to the one in Section 3, but further demonstrates how to "start", "check", and "kill" a **pbdCS** cluster with 4 R launched by/within the MPI program `mpiexec`.

In an well established server, one can use `ssh` or `plink.exe` to send those commands from the local laptop. Furthermore, one may also use **pbdRPC** directly within an R environment to send those commands. The example is in next.

Using **pbdRPC** to control **pbdCS**

```
> library(pbdRPC, quietly = TRUE)
>
> ### Alter login information as needed
> rpcopt_set(user = "snoweye", hostname = "192.168.56.101")
> .pbd_env$RPC.CT$use.shell.exec <- FALSE
>
> preload <- "source ~/work-my/00_set_devel_R; "
> start_cs(preload = preload)
character(0)
```

```
>
> library(pbdCS)
> pbdCS::pbdclient(addr = "192.168.56.101")

pbdR> library(pbdMPI)
pbdR> allreduce(1)
[1] 4
pbdR> q()
>
> check_cs()
[1] "12578 ?        Sl     0:00 mpiexec -np 4 Rscript -e
   pbdCS::pbdserver()"
[2] "12580 ?        Sl     0:00
   /home/snoweye/work-my/local/R-devel/lib64/R/bin/exec/R --slave
   --no-restore -e pbdCS::pbdserver()"
[3] "12581 ?        Sl     0:00
   /home/snoweye/work-my/local/R-devel/lib64/R/bin/exec/R --slave
   --no-restore -e pbdCS::pbdserver()"
[4] "12583 ?        Sl     0:00
   /home/snoweye/work-my/local/R-devel/lib64/R/bin/exec/R --slave
   --no-restore -e pbdCS::pbdserver()"
[5] "12588 ?        Sl     0:00
   /home/snoweye/work-my/local/R-devel/lib64/R/bin/exec/R --slave
   --no-restore -e pbdCS::pbdserver()"
> kill_cs()
character(0)
```

where `pbdclient()` is for connect to the **pbdCS** cluster started by `start_cs()`.

The `start_cs()`, `check_cs()`, and `kill_cs()` are all wrapper functions of `rpc()` to submit different commands stored in `.pbd_env$RPC.CS$start`, `.pbd_env$RPC.CS$check`, and `.pbd_env$RPC.CS$kill`, respectively. The details of `RPC.CS` are in next.

`RPC.CS` for controlling **pbdCS**

```
> .pbd_env$RPC.CS
$check
[1] "ps ax|grep '[p]bdCS::pbdserver'"

$kill
[1] "kill -9 $(ps ax|grep '[p]bdCS::pbdserver'|awk '{print $1}')"

$start
[1] "nohup mpiexec -np 4 Rscript -e 'pbdCS::pbdserver()' > .cslog
   2>&1 < /dev/null &"

$preload
[1] "source ~/work-my/00_set_devel_R; "
```

5. Local Port Forwarding

Warning:

System security issues may raise when the materials of this section are implemented in open/public domains. Consulting with network security experts may be required.

The **remoter** command `client()` has a default setting to connect to the **remoter** server using `addr = "localhost"` and `port = 55555` which assumes the **remoter** server and client are both working at `localhost`. This may only be possible for convenience of development and debugging only. In general, the server can be anywhere and more powerful than a laptop. Again, We may consider the environment setup in Sections 3 and 4 to demonstrate local port forwarding, even though the setup is over simplified it is quite common for most general users. The server is running at `192.168.56.101:55555`, so the argument `addr = "192.168.56.101"` in the **remoter** command `client(addr = "192.168.56.101")` from the `localhost` is necessary.

Note that this above case may not be a good reason to show local port forwarding. However, it can avoid typing address or to be independent to the `addr`. One may consider to forward the `localhost` port `55555` to the server directly.

The following code serves the purpose of local port forwarding in **pbdRPC** using `rpc()`, then start a **remoter** server and launch a connection via `client()` without changing arguments.

Forward `localhost:55555` to `192.168.56.101:55555`

```
> library(pbdRPC)
> rpc(args = "-N -T -L 55555:192.168.56.101:55555", wait = FALSE)
> start_rr()
>
> library(remoter)
> client()     # equivalent to client(addr = "192.168.56.101")
```

First, `rpc(args = "-N -T -L 55555:192.168.56.101:55555")` forwards the connection between `55555` of the local host and `192.168.56.101:5555`. Note that this call (local process) is running in background and is not disconnected even after quiting R, because `intern = FALSE` (default) and `wait = FALSE` are set to `rpc()` and passed down to its callee (in a shell). The additional command "`kill -p [pid]`" may be needed to manually kill the local process (pid) when the forwarding is not needed anymore. See Section 5.1 or `ssh`'s man page for details of arguments `-N -T -L` (inside `args`) to the `ssh` or `plink.exe`.

Second, `client()` tries to connect with `localhost:55555` by default because it is from the laptop. The connection is then redirected to `192.168.56.101:5555` as well because the local port is being forwarded.

5.1. Arguments for Local Port Forwarding

Note that the `ssh` and `plink.exe` has similar functionalities for local port forwarding.

The argument `-L` in `ssh` or `plink.exe` is a typical option for local port forwarding. The usage from the man page of the `ssh` says

From `ssh` man page

```
-L [bind_address:]port:host:hostport
      Specifies that the given port on the local (client) host is
```

```
      to be forwarded to the given host and port on the remote side.
      ... skipped ...
```

Because the call of local port forwarding needs to be either alive or active during the access of other applications to the `[bind_address:]port`, two other useful arguments are `-N` and `-T` that can combine and use with local port forwarding. The usages of both arguments from the man page say

From `ssh` man page

```
-N    Do not execute a remote command.  This is useful for just
      for warding ports (protocol version 2 only).
-T    Disable pseudo-terminal allocation.
```

i.e. batch and background modes are preferable.

5.2. Arguments for Tunneling

Theoretically, this is possible to be used in `rpc()`. However, there is no appropriate example yet.

Note that the `ssh` and `plink.exe` has similar functionalities for local port forwarding.

The argument `-R` in `ssh` or `plink.exe` is a typical option for tunneling. The usage from the man page of the `ssh` says

From `ssh` man page

```
-R [bind_address:]port:host:hostport
      Specifies that the given port on the remote (server) host is to
      be forwarded to the given host and port on the local side.
      ... skipped ...
```

6. An Advance Application with pbdMPI

Examples of the **pbdMPI** (Chen *et al.* 2012) are introduced in this section first under a shell/terminal mode. Then, the examples will be combined with **pbdRPC** to show how `rpc()` sends requests from an interactive R session to a remote server and execute the examples in the shell/terminal model. Multiple commands can be manually combined in one `rpc()` call. The return values can also be captured by the interactive R session with an addition argument.

The **pbdMPI** is a general MPI interface running in SPMD by default. A typical example is to run the **pbdMPI** via `mpiexec` and `Rscript` from a shell/terminal as in below with outputs.

`pbdMPI::allreduce(1)` in 4 cores

```
$ mpiexec -np 4 Rscript -e
   'library(pbdMPI,quietly=T);allreduce(1);finalize()'
[1] 4
[1] 4
[1] 4
[1] 4
```

The outputs are printed from 4 cores. Each core has a `allreduce(1)` call synchronically to reduce three 1's from other peer cores. The default operation for `allreduce()` is a summation `sum()`, so the total is 4. Note that the 4 cores may not be in a single machine as long as MPI setup correctly.

Similary, the example below will give the total 8 in each core because the value to be reduced is 2 from each core at this time.

`pbdMPI::allreduce(2)` in 4 cores

```
$ mpiexec -np 4 Rscript -e
   'library(pbdMPI,quietly=T);allreduce(2);finalize()'
[1] 8
[1] 8
[1] 8
[1] 8
```

With the examples above, one may want to execute them from a local machine/laptop. i.e. **pbdMPI** is run on remote servers while **pbdRPC** is run in local. Note that two systems between server and local machine are generally different.

Assume environment setups are similar as Sections 3 and 4. The **pbdRPC** commands within an interactive R session are shown below.

pbdRPC in local and **pbdMPI** in remote

```
> library(pbdRPC)
>
> ### Alter login information as needed
> rpcopt_set(user = "snoweye", hostname = "192.168.56.101")
> .pbd_env$RPC.CT$use.shell.exec <- FALSE
>
> ### Set the RPC commands
> preload <- "source ~/work-my/00_set_devel_R; "
> cmd.mpi <- "mpiexec -np 4 Rscript -e "
> cmd.code <- "'library(pbdMPI,quietly=T);allreduce(3);finalize()'"
>
> ### Put the RPC commands together
> cmd <- paste(preload, cmd.mpi, cmd.code, sep = "")
> cmd  ### Similar to the shell example above
>
> ### Send the command to remote server, snoweye@192.168.56.101
> rpc(cmd = cmd)
[1][1] 12
[1] 12
[1] 12
12
>
> ### Capture the return values
> ret <- rpc(cmd = cmd, intern = TRUE)
> str(ret)
 chr [1:4] "[1] 12" "[1] 12" "[1] 12" "[1] 12"
> ret
[1] "[1] 12" "[1] 12" "[1] 12" "[1] 12"
```

In order to capture the return values (four character strings) from the remote server, the argument `intern = TRUE` set to the `rpc()` is required as shown in the example.

7. FAQs

7.1. General

1. **Q:** Does **pbdRPC** support Windows system?
   A: Yes, the `plink.exe` from PuTTY will be the program to send commands to remote servers. An internal built `plink.exe` will be provided and wrapped by the **pbdRPC** command `plink()`.

2. **Q:** Is an authentication used in **pbdRPC**? How does it work?
   A: Yes, the authentication is the same way to `ssh` and `plink.exe` provided public and private keys are setup correctly. For example, when an RSA key is used, the `ssh` will by default search `~/.ssh/id_rsa` or via the option "`-i ./id_rsa`" for a local private key. Similarly, the `plink.exe` uses the option "`-i ./id_rsa.ppk`" for a local private key. Inside **pbdRPC**, one can use the options of the control `.pbd_env$RPC.LI$priv.key` and `.pbd_env$RPC.LI$pri.key.ppk` to indicate the file of the private key. Then, `ssh()`, `plink()`, and `rpc()` commands will automatically access those files, accordingly.

3. **Q:** Can a `ssh` private key be converted to `plink`'s private key? i.e. convert OpenSSH format to PuTTY format.
   A: Yes, the `puttygen` on linux can convert the `id_rsa` (OpenSSH format) to `id_rsa.ppk` (PuTTY format) as in next.

   Shell Command

   ```
   $ sudo apt-get install putty
   $ puttygen id_rsa -O private -o id_rsa.ppk
   ```

4. **Q:** Is it possible to capture the returns from the RPC calls by `rpc()`, `ssh()`, or `plink()`? How?
   A: Yes, set the arguments `intern = TRUE` and `wait = TRUE` to the RPC calls can obtain the outputs as used by `system()`. The `plink()` used in `RGui` may not be able to capture the outputs unless the authentication is set because `shell.exec()` is used instead of `system()`.

5. **Q:** Does `rpc()` support `SSH` (reverse/remote) tunneling or port forwarding?
   A: Yes, theoretically there is no problem. However, there is no appropriate example to show that in R.

6. **Q:** Error messages from an R session or a shell/terminal are shown as below.

   Error Message

   ```
   FATAL ERROR: Network error: Connection refused
   ```

   or

Error Message

```
ssh: connect to host 192.168.56.101 port 22: Connection refused
```

A: The messages are mainly because of incorrect setups of SSH service. Check SSH service on remote servers.

- Install SSH server, such as in next.

  Shell Command

  ```
  $ sudo apt-get install openssh-server
  ```

- Check network, port, SSH service, and firewall configurations.
- Turn on connection permissions for SSH ports.
- Make sure password or authentication are correct.

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