

Checkpointing

Olivier Mattelaer



What is
checkpointing



\$./count

\$./count
1

```
$ ./count
```

```
1
```

```
2
```

\$./count

1

2

3

\$./count

1

2

3^C

\$

\$./count

1

2

3^C

\$./count

\$./count

1

2

3^C

\$./count

1

Without checkpointing:

```
$ ./count
```

```
1
```

```
2
```

```
3^C
```

```
$ ./count
```

```
1
```

Without checkpointing:

\$./count

1

2

3^C

\$./count

1

With checkpointing:

\$./count

1

2

3^C

\$./count

4

Without checkpointing:

```
$ ./count
```

```
1
```

```
2
```

```
3^C
```

```
$ ./count
```

```
1
```

```
2
```

With checkpointing:

```
$ ./count
```

```
1
```

```
2
```

```
3^C
```

```
$ ./count
```

```
4
```

```
5
```

Without checkpointing:

\$./count

1

2

3^C

\$./count

1

2

3

With checkpointing:

\$./count

1

2

3^C

\$./count

4

5

6

Without checkpointing:

With checkpointing:

Checkpointing:

'saving' a computation
so that it can be resumed later
(rather than started again)

Checkpointing

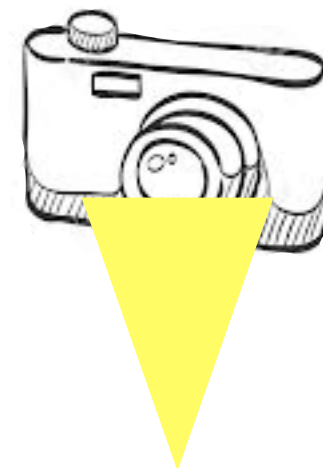
Software

- If the software has (even partial) internal checkpointing: use it !
- Typically lightweight
- At meaningful time



Hardware

- If software specific is not available (or not enough)
- Dump the RAM/... on disk
 - Heavy/slow
- Can be done any time

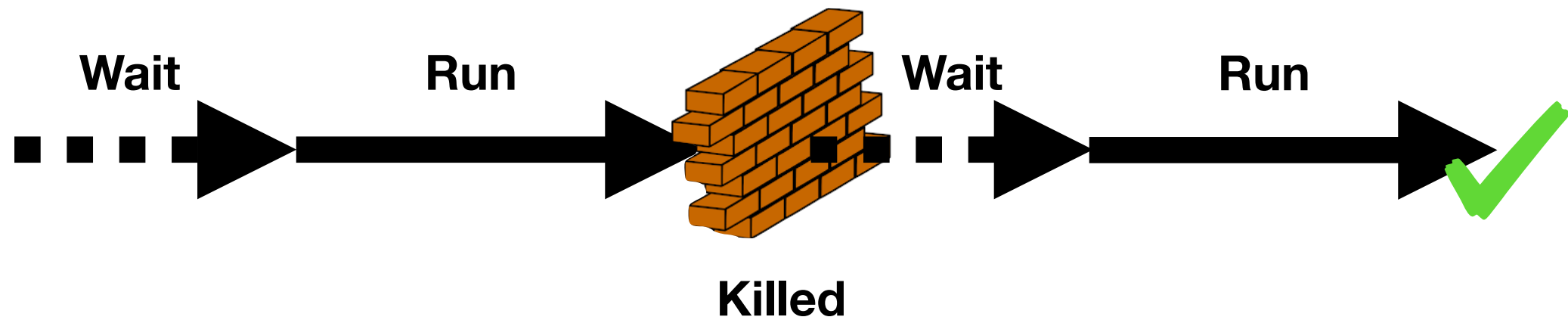




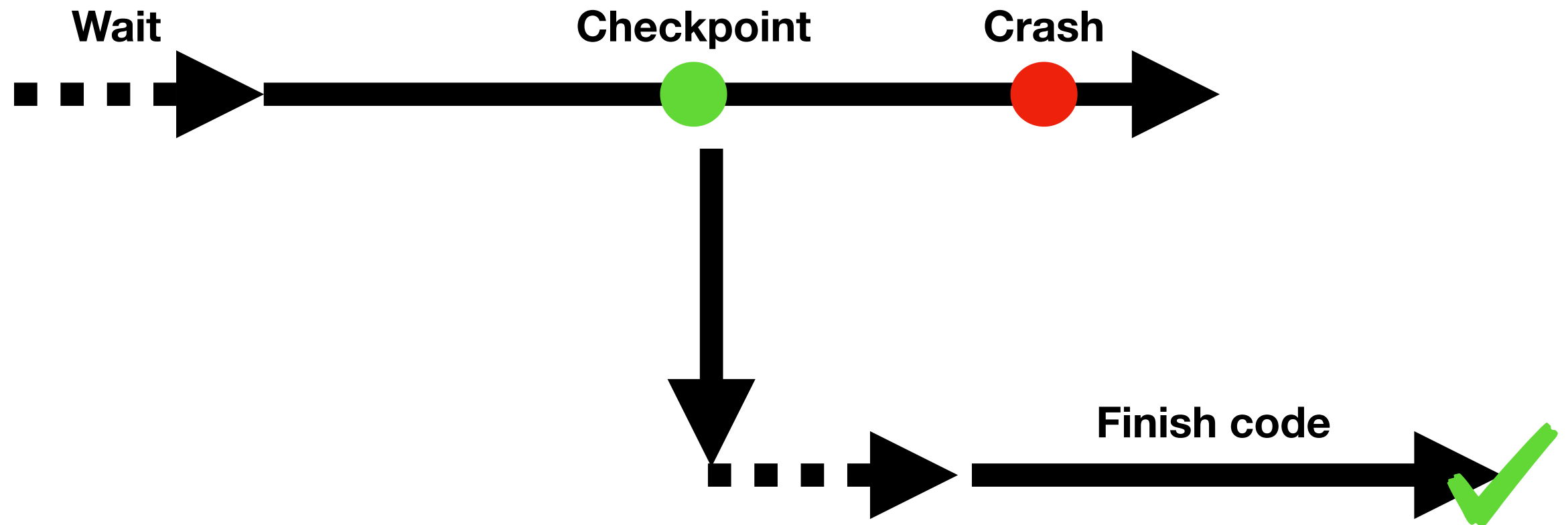
Why do we need
checkpointing



Wall-Time



Hardware crash



Today Agenda

- How to checkpoint every **iteration**.
 - Easy just setting the stage
- How to checkpoint **on demand**.
 - Signal
 - Every X minutes

Today Agenda

- How to checkpoint every **iteration**.
 - Easy just setting the stage

Software

- How to checkpoint **on demand**.
 - Signal

- Every X minutes

Hardware

Demo #1

count.py

Save state at each iteration



2

Using UNIX signals to reduce overhead : do not save the state at each iteration -- wait for the signal.

UNIX processes can receive 'signals' from the user, the OS, or another process

SIGHUP	1	Exit	Hangup
SIGINT	2	Exit	Interrupt
SIGQUIT	3	Core	Quit
SIGILL	4	Core	Illegal Instruction
SIGTRAP	5	Core	Trace/Breakpoint Trap
SIGABRT	6	Core	Abort
SIGEMT	7	Core	Emulation Trap
SIGFPE	8	Core	Arithmetic Exception
SIGKILL	9	Exit	Killed
SIGBUS	10	Core	Bus Error
SIGSEGV	11	Core	Segmentation Fault
SIGSYS	12	Core	Bad System Call
SIGPIPE	13	Exit	Broken Pipe
SIGALRM	14	Exit	Alarm Clock
SIGTERM	15	Exit	Terminated
SIGUSR1	16	Exit	User Signal 1
SIGUSR2	17	Exit	User Signal 2
SIGCHLD	18	Ignore	Child Status
SIGPWR	19	Ignore	Power Fail/Restart
SIGWINCH	20	Ignore	Window Size Change
SIGURG	21	Ignore	Urgent Socket Condition
SIGPOLL	22	Ignore	Socket I/O Possible
SIGSTOP	23	Stop	Stopped (signal)
SIGTSTP	24	Stop	Stopped (user)
SIGCONT	25	Ignore	Continued
SIGTTIN	26	Stop	Stopped (tty input)
SIGTTOU	27	Stop	Stopped (tty output)
SIGVTALRM	28	Exit	Virtual Timer Expired
SIGPROF	29	Exit	Profiling Timer Expired
SIGXCPU	30	Core	CPU time limit exceeded
SIGXFSZ	31	Core	File size limit exceeded
SIGWAITING	32	Ignore	All LWPs blocked
SIGLWP	33	Ignore	Virtual Interprocessor Interrupt for Threads Library
SIGAIO	34	Ignore	Asynchronous I/O

UNIX processes can receive 'signals' from the user, the OS, or another process

^C —

^D —

SIGHUP	1	Exit	Hangup
SIGINT	2	Exit	Interrupt
SIGQUIT	3	Core	Quit
SIGILL	4	Core	Illegal Instruction
SIGTRAP	5	Core	Trace/Breakpoint Trap
SIGABRT	6	Core	Abort
SIGEMT	7	Core	Emulation Trap
SIGFPE	8	Core	Arithmetic Exception
SIGKILL	9	Exit	Killed
SIGBUS	10	Core	Bus Error
SIGSEGV	11	Core	Segmentation Fault
SIGSYS	12	Core	Bad System Call
SIGPIPE	13	Exit	Broken Pipe
SIGALRM	14	Exit	Alarm Clock
SIGTERM	15	Exit	Terminated
SIGUSR1	16	Exit	User Signal 1
SIGUSR2	17	Exit	User Signal 2
SIGCHLD	18	Ignore	Child Status
SIGPWR	19	Ignore	Power Fail/Restart
SIGWINCH	20	Ignore	Window Size Change
SIGURG	21	Ignore	Urgent Socket Condition
SIGPOL	22	Ignore	Socket I/O Possible
SIGSTOP	23	Stop	Stopped (signal)
SIGTSTP	24	Stop	Stopped (user)
SIGCONT	25	Ignore	Continued
SIGTTIN	26	Stop	Stopped (tty input)
SIGTTOU	27	Stop	Stopped (tty output)
SIGVTALRM	28	Exit	Virtual Timer Expired
SIGPROF	29	Exit	Profiling Timer Expired
SIGXCPU	30	Core	CPU time limit exceeded
SIGXFSZ	31	Core	File size limit exceeded
SIGWAITING	32	Ignore	All LWP's blocked
SIGLWP	33	Ignore	Virtual Interprocessor Interrupt for Threads Library
SIGAI	34	Ignore	Asynchronous I/O

^Z —

— kill -9

— kill

— fg, bg

Demo #2

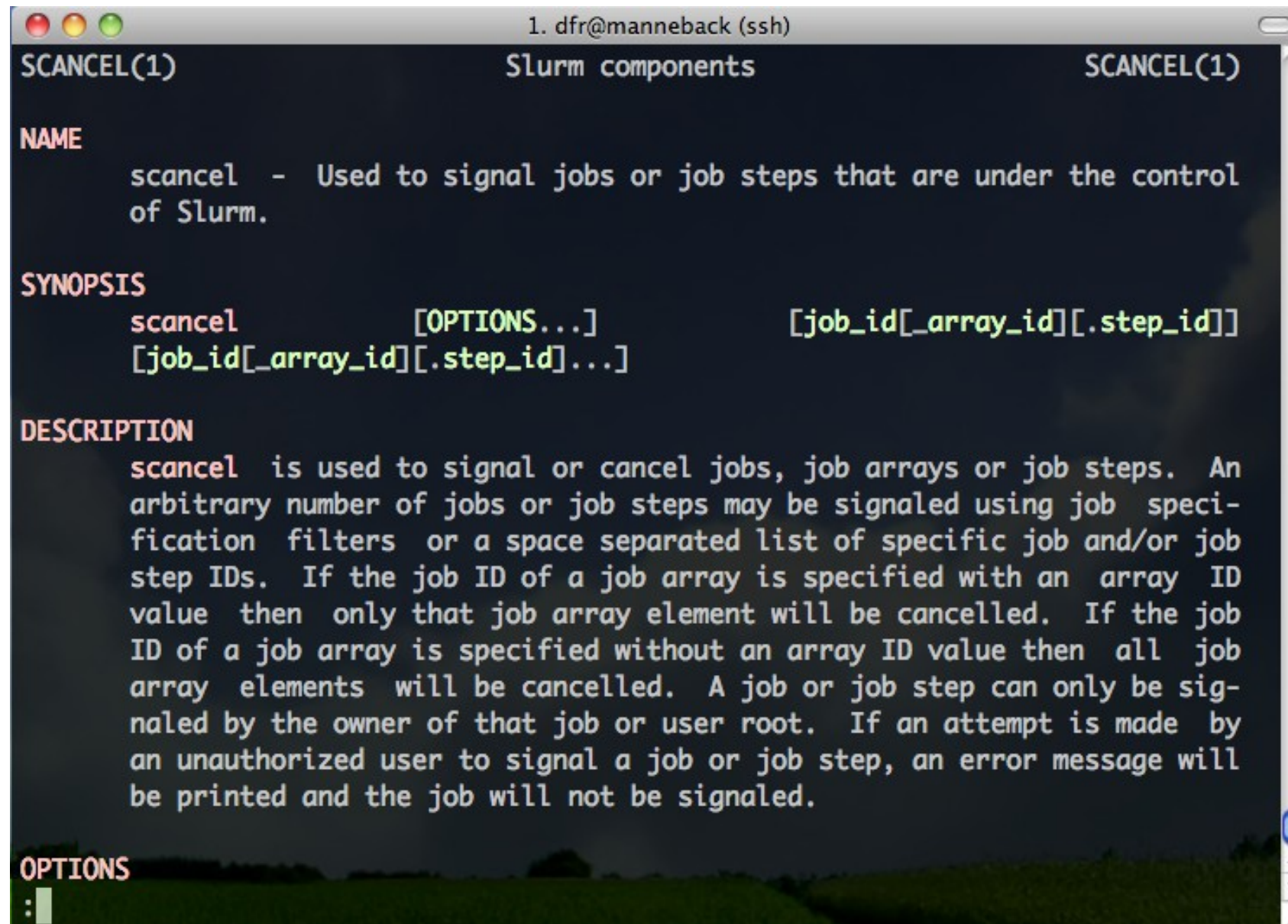
`count-signal.py`

Catch control-C to save state



3 Use Slurm signaling abilities to manage checkpoint-able software in Slurm scripts on the clusters.

scancel is used to send signals to jobs

A terminal window titled "1. dfr@manneback (ssh)" displays the man page for the 'scancel' command. The window has a dark background with light-colored text. The man page content is as follows:

```
SCANCEL(1)                                Slurm components                                SCANCEL(1)

NAME
    scancel - Used to signal jobs or job steps that are under the control
              of Slurm.

SYNOPSIS
    scancel      [OPTIONS...]          [job_id[_array_id][.step_id]]
    [job_id[_array_id][.step_id]...]

DESCRIPTION
    scancel is used to signal or cancel jobs, job arrays or job steps. An
    arbitrary number of jobs or job steps may be signaled using job speci-
    fication filters or a space separated list of specific job and/or job
    step IDs. If the job ID of a job array is specified with an array ID
    value then only that job array element will be cancelled. If the job
    ID of a job array is specified without an array ID value then all job
    array elements will be cancelled. A job or job step can only be sig-
    naled by the owner of that job or user root. If an attempt is made by
    an unauthorized user to signal a job or job step, an error message will
    be printed and the job will not be signaled.

OPTIONS
    :
```

scancel -s SIGINT JOBID

Just in time checkpointing



Just in time checkpointing



Slurm has options for that

Just in time checkpointing



Slurm has options for that

--signal=SIGINT@60

send signal 60s before the wall-time

Signal will be send to the **srun command** of your script

--signal=B:SIGINT@120

send signal 120s before the wall-time

Signal will be send to the slurm **submission script**

Just in time checkpointing



Slurm has options for that

`--signal=SIGINT@60`

send signal 60s before the wall-time

Signal will be send to the **srun command** of your script

`--signal=B:SIGINT@120`

send signal 120s before the wall-time

Signal will be send to the slurm **submission script**

Slurm can auto-requeue

Note the --open-mode=append

```
root@lm3-m001:~ (ssh)
File Edit Options Buffers Tools Sh-Script Help
#!/bin/bash

#SBATCH --job-name=test
#SBATCH --output=test.signal
#SBATCH --open-mode=append
#SBATCH --time=0-00:03:00
#SBATCH --signal=SIGINT@60
#SBATCH --ntasks=1
#SBATCH --partition=debug

date
echo "restarted ${SLURM_RESTART_COUNT-0}"
module load Python/2.7.14-foss-2017b
python --version
srun --overcommit -n1 python ./count-signal.py
```

Note that we need the srun here

Adding requeuing automatically

```
root@lm3-m001:~ (ssh)
File Edit Options Buffers Tools Sh-Script Help
#!/bin/bash

#SBATCH --job-name=test
#SBATCH --output=test.signal.watch
#SBATCH --open-mode=append
#SBATCH --time=0-00:05:00
#SBATCH --signal=B:USR1@60
#SBATCH --ntasks=1
#SBATCH --partition=debug

timeout()
{
    echo "TRAPPED"
    scancel -s SIGINT $SLURM_JOB_ID
    scontrol requeue $SLURM_JOB_ID
}

# call your_cleanup_function once we receive USR1 signal
trap 'timeout' USR1

date
echo "restarted ${SLURM_RESTART_COUNT-0}"
module load Python/2.7.14-foss-2017b
srun --overcommit -n1 python /home/ucl/cp3/omatt/checkpointing/count.py &
wait
```

Send signal to bash with USR1

Catch the signal (USR1)
-> send ^C to python script (save state)
-> re-queue the job

Important here!

Demo #3

`slurm-signal-3.sh`

Slurm send USR1 between 1 and 2 minutes
Bash catch the message send Ctrl-c to python
python: Catch control-C to save state
Automatic resubmission

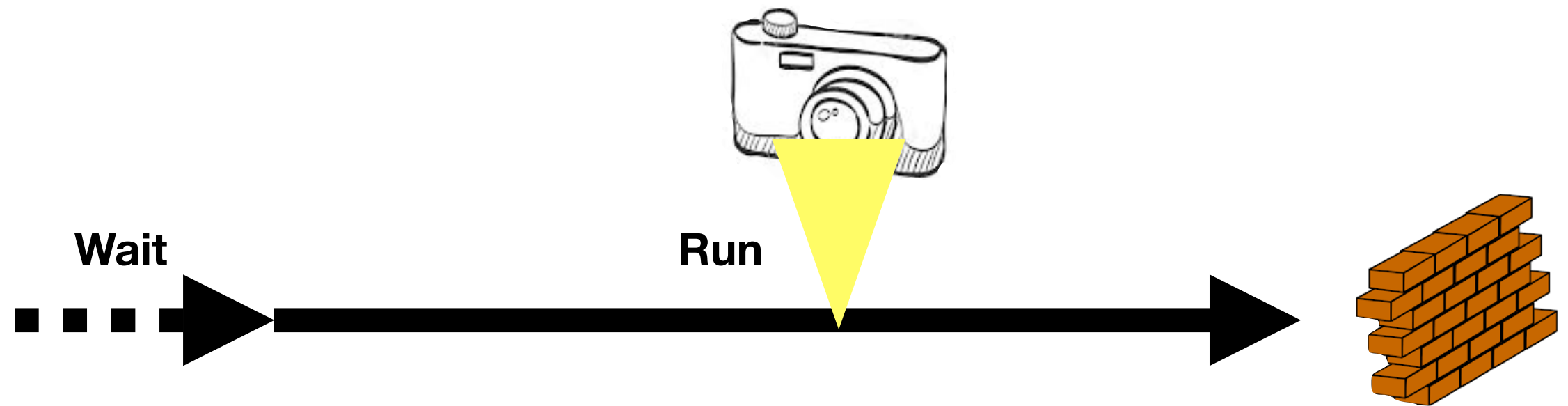


4 Making non restartable software restartable with DMTCP

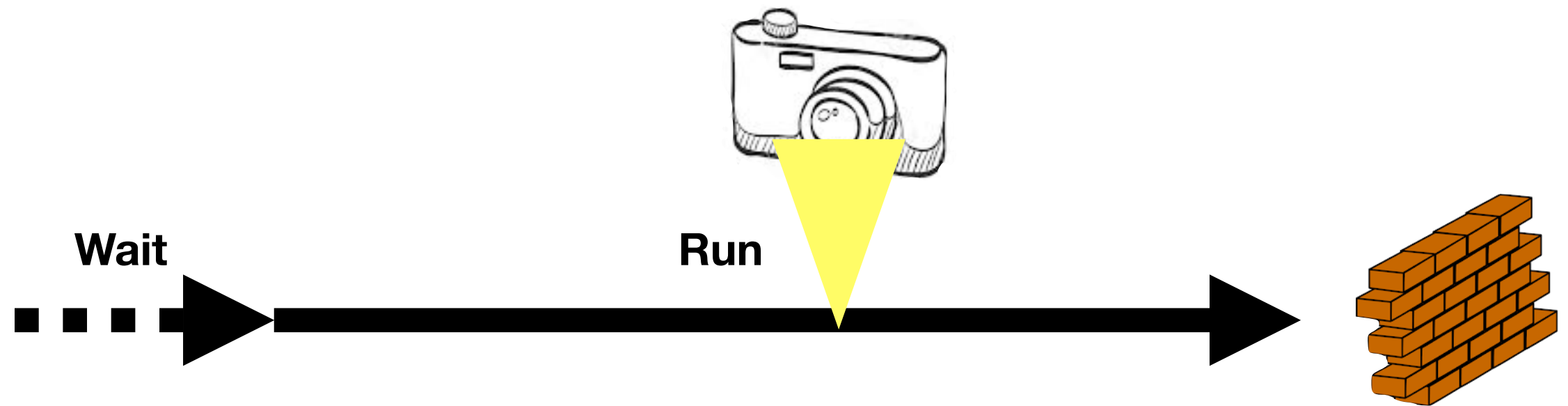
NO code access



NO code access

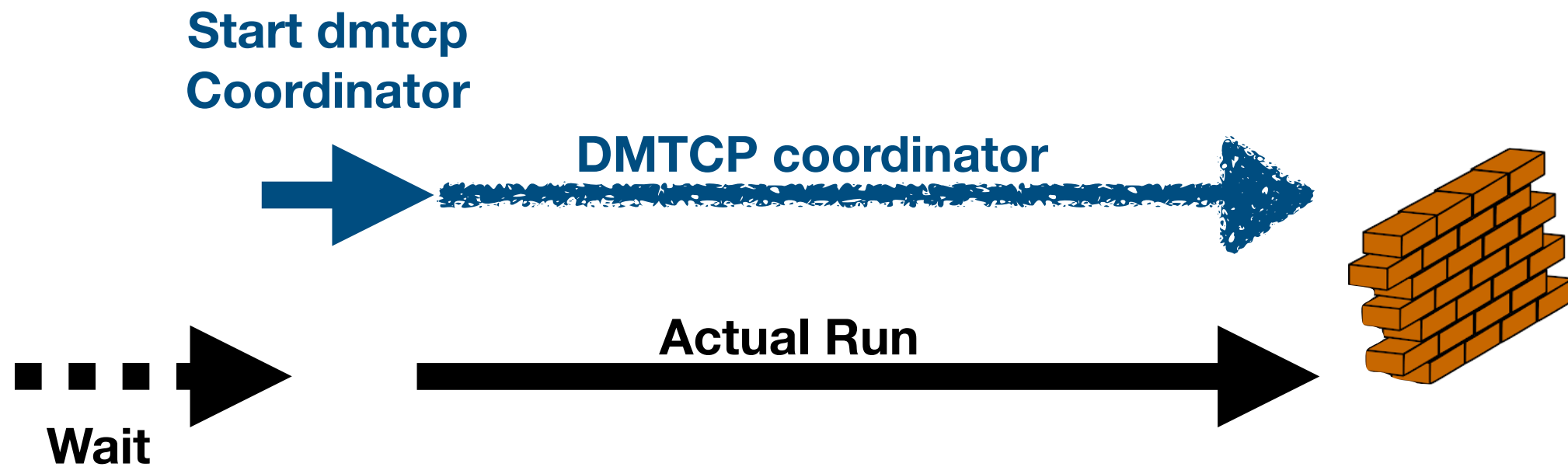


NO code access



MPI
SLURM
Infiniband

DMTCP mode



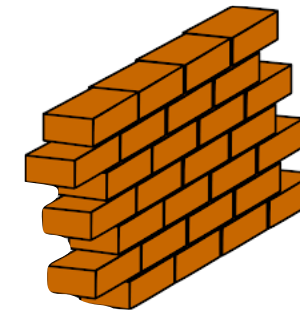
```
$> Module load DMTCP
```

```
$> dmtcp_launch XXX
```

DMTCP mode

Mode #1: Snapshot every X second

**Start dmtcp
Coordinator**



Wait



Actual Run



```
$> Module load DMTCP
```

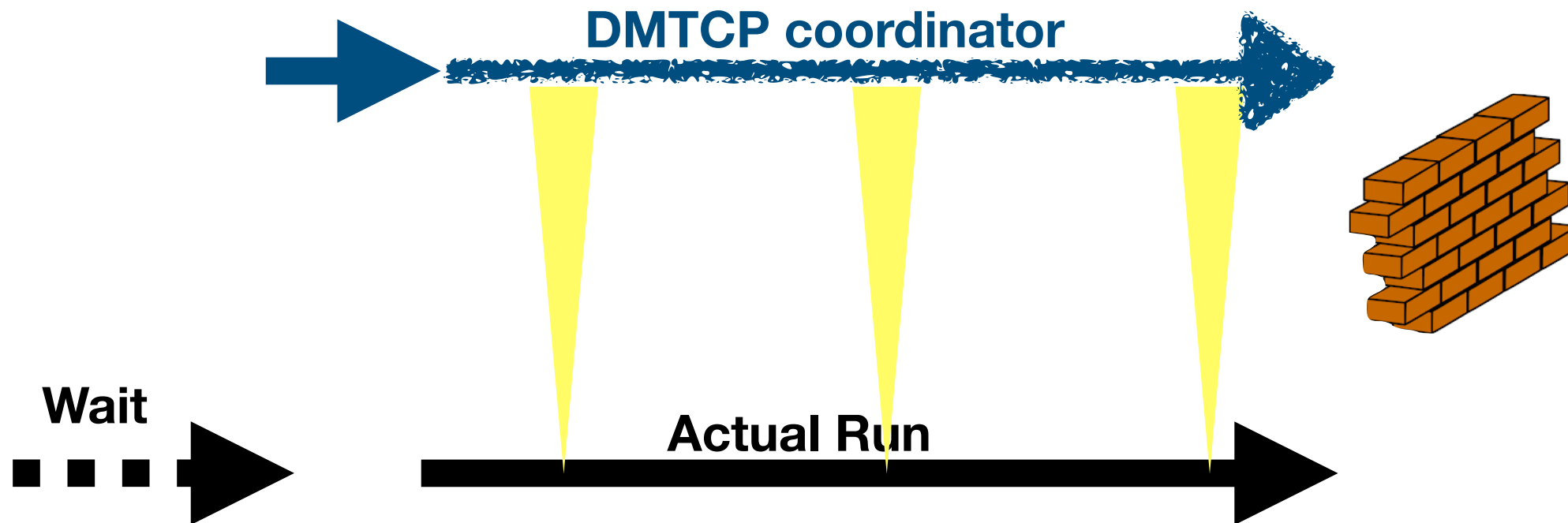
```
$> dmtcp_launch XXXX
```

```
$> dmtcp_command --bcheckpoint
```


DMTCP mode

Mode #1: Snapshot every X second

Start dmtcp
Coordinator

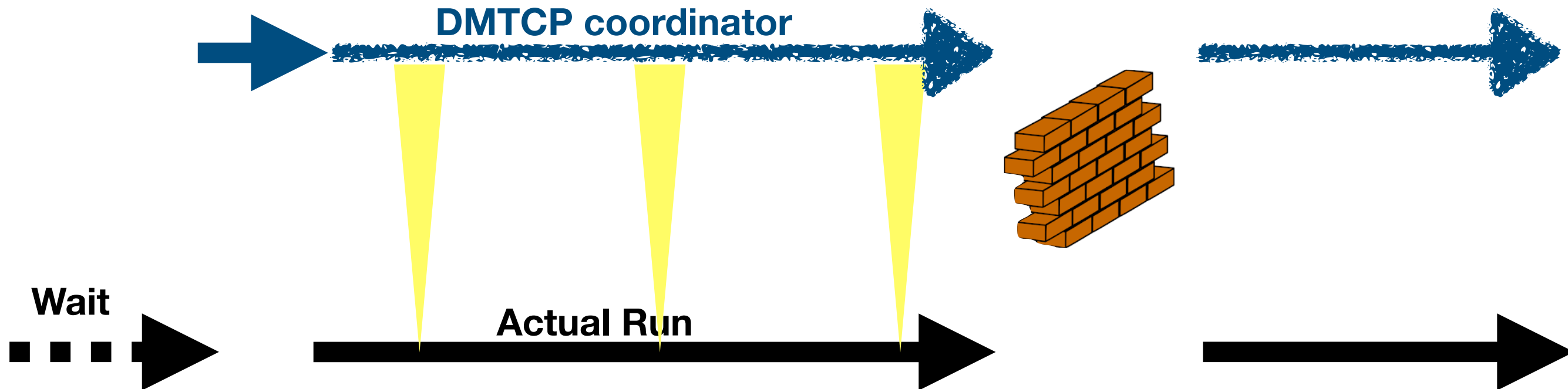


```
$> Module load DMTCP  
$> dmtcp_launch XXXX  
$> dmtcp_command --bcheckpoint
```

DMTCP mode

Mode #1: Snapshot every X second

Start dmtcp
Coordinator



```
$> Module load DMTCP  
$> dmtcp_launch XXXX  
$> dmtcp_command --bcheckpoint
```

```
$> ./dmtcp_restart_script.sh
```

Apply it for Slurm

```
#####  
# 1. Start DMTCP coordinator  
#####  
  
start_coordinator -i 10 # -i 120 ... <put dmtcp coordinator options here>  
  
#####  
# 2. Launch application  
# 2.1. If you use mpiexec/mpirun to launch an application, use the following  
#       command line:  
#       $ dmtcp_launch --rm mpiexec <mpi-options> ./<app-binary> <app-options>  
# 2.2. If you use PMI1 to launch an application, use the following command line:  
#       $ srun dmtcp_launch --rm ./<app-binary> <app-options>  
# Note: PMI2 is not supported yet.  
# 2.3. If you use the Stampede supercomputer at Texas Advanced Computing Center  
#       (TACC), use ibrun command to launch the application (--rm is not required):  
#       $ ibrun dmtcp_launch ./<app-binary> <app-options>  
#####  
srun dmtcp_launch --allow-file-overwrite python -u count-orig.py 10<&- 11>&-
```

**start coordinator
Snapshot every 10s**

**Normal job with
decorator**

Resubmit

```
#----- Launch application -----#

#####
# 1. Start DMTCP coordinator
#####

start_coordinator -i 10 # -i 120 ... <put dmtcp coordinator options here>

#####
# 2. Restart application
#####

/bin/bash ./dmtcp_restart_script.sh -h $DMTCP_COORD_HOST -p $DMTCP_COORD_PORT

#####
# If you use the Stampede supercomputer at Texas Advanced Computing Center
# (TACC), add the --hostfile option:
# /bin/bash ./dmtcp_restart_script.sh -h $DMTCP_COORD_HOST -p $DMTCP_COORD_PORT\
#                               --hostfile $HOSTFILE
#####
```

start coordinator

**Script created by
previous run**

Let's combine everything

Use DMTCP with periodic check
add an additional checkpoint before wall time
Auto resubmit

Solution

```
#!/bin/bash
# Put your SLURM options here
#SBATCH --partition=debug          # change to proper partition name or remove
#SBATCH --time=00:00:30           # put proper time of reservation here
#SBATCH --nodes=1                 # number of nodes
#SBATCH --ntasks-per-node=1       # processes per node
#SBATCH --job-name="dmtcp_job"    # change to your job name
#SBATCH --output=slurm.dmtcp      # change to proper file name or remove for defaults
#SBATCH --signal=B:USR1@60
#SBATCH --open-mode=append
```

```
#####
# 1. Start DMTCP coordinator
#####

start_coordinator -i 10 # -i 120 ... <put dmtcp coordinator options here>

#####
# 2. Launch application
#####
echo "requeue #${SLURM_RESTART_COUNT}"

if [[ -e dmtcp_restart_script.sh && "${SLURM_RESTART_COUNT}" != "" ]]; then
    /bin/bash ./dmtcp_restart_script.sh -h $DMTCP_COORD_HOST -p $DMTCP_COORD_PORT &
else
    srun dmtcp_launch --allow-file-overwrite      python -u count-orig.py 10<&- 11>&- &
fi

#####
# 3. setup requeue for the wall time
# Note the #SBATCH --signal=B:USR1@60 which is needed
#####
timeout(){
echo "doing checkpoint"
dmtcp_command --bcheckpoint
sleep 2
echo "doing checkpoint; done"
dmtcp_command --quit
sleep 2
scontrol requeue $SLURM_JOB_ID
}

trap 'timeout' USR1
wait
```

Solution

Periodic checkpoint

```
#!/bin/bash
# Put your SLURM options here
#SBATCH --partition=debug          # change to proper partition name or remove
#SBATCH --time=00:00:30           # put proper time of reservation here
#SBATCH --nodes=1                 # number of nodes
#SBATCH --ntasks-per-node=1       # processes per node
#SBATCH --job-name="dmtcp_job"    # change to your job name
#SBATCH --output=slurm.dmtcp      # change to proper file name or remove for defaults
#SBATCH --signal=B:USR1@60
#SBATCH --open-mode=append
```

```
#####
# 1. Start DMTCP coordinator
#####
start_coordinator -i 10 # -i 120 ... <put dmtcp coordinator options here>

#####
# 2. Launch application
#####
echo "requeue #${SLURM_RESTART_COUNT}"

if [[ -e dmtcp_restart_script.sh && "${SLURM_RESTART_COUNT}" != "" ]]; then
    /bin/bash ./dmtcp_restart_script.sh -h $DMTCP_COORD_HOST -p $DMTCP_COORD_PORT &
else
    srun dmtcp_launch --allow-file-overwrite      python -u count-orig.py 10<&- 11>&- &
fi

#####
# 3. setup requeue for the wall time
# Note the #SBATCH --signal=B:USR1@60 which is needed
#####
timeout(){
echo "doing checkpoint"
dmtcp_command --bcheckpoint
sleep 2
echo "doing checkpoint; done"
dmtcp_command --quit
sleep 2
scontrol requeue $SLURM_JOB_ID
}

trap 'timeout' USR1
wait
```


Solution

Periodic checkpoint
Checkpoint at walltime

```
#!/bin/bash
# Put your SLURM options here
#SBATCH --partition=debug           # change to proper partition name or remove
#SBATCH --time=00:00:30             # put proper time of reservation here
#SBATCH --nodes=1                   # number of nodes
#SBATCH --ntasks-per-node=1         # processes per node
#SBATCH --job-name="dmtcp_job"      # change to your job name
#SBATCH --output=slurm_dmtcp        # change to proper file name or remove for defaults
#SBATCH --signal=B:USR1@60
#SBATCH --open-mode=append

#####
# 1. Start DMTCP coordinator
#####

start_coordinator -i 10 # -i 120 ... <put dmtcp coordinator options here>

#####
# 2. Launch application
#####
echo "requeue #${SLURM_RESTART_COUNT}"

if [[ -e dmtcp_restart_script.sh && "${SLURM_RESTART_COUNT}" != "" ]]; then
    /bin/bash ./dmtcp_restart_script.sh -h $DMTCP_COORD_HOST -p $DMTCP_COORD_PORT &
else
    srun dmtcp_launch --allow-file-overwrite      python -u count-orig.py 10<&- 11>&- &
fi

#####
# 3. setup requeue for the wall time
# Note the #SBATCH --signal=B:USR1@60 which is needed
#####
timeout(){
    echo "doing checkpoint"
    dmtcp_command --bcheckpoint
    sleep 2
    echo "doing checkpoint; done"
    dmtcp_command --quit
    sleep 2
    scontrol requeue $SLURM_JOB_ID
}

trap 'timeout' USR1
wait
```


Solution

Periodic checkpoint
Checkpoint at walltime

```
#!/bin/bash
# Put your SLURM options here
#SBATCH --partition=debug          # change to proper partition name or remove
#SBATCH --time=00:00:30           # put proper time of reservation here
#SBATCH --nodes=1                 # number of nodes
#SBATCH --ntasks-per-node=1       # processes per node
#SBATCH --job-name="dmtcp_job"     # change to your job name
#SBATCH --output=slurm.dmtcp       # change to proper file name or remove for defaults
#SBATCH --signal=B:USR1@60
#SBATCH --open-mode=append

#####
# 1. Start DMTCP coordinator
#####

start_coordinator -i 10 # -i 120 ... <put dmtcp coordinator options here>

#####
# 2. Launch application
#####
echo "requeue #${SLURM_RESTART_COUNT}"

if [[ -e dmtcp_restart_script.sh && "${SLURM_RESTART_COUNT}" != "" ]]; then
    /bin/bash ./dmtcp_restart_script.sh -h $DMTCP_COORD_HOST -p $DMTCP_COORD_PORT &
else
    srun dmtcp_launch --allow-file-overwrite      python -u count-orig.py 10<&- 11>&- &
fi

#####
# 3. setup requeue for the wall time
# Note the #SBATCH --signal=B:USR1@60 which is needed
#####
timeout(){
echo "doing checkpoint"
dmtcp_command --bcheckpoint
sleep 2
echo "doing checkpoint; done"
dmtcp_command --quit
sleep 2
scontrol requeue $SLURM_JOB_ID
}

trap 'timeout' USR1
wait
```

Solution

Periodic checkpoint
Checkpoint at walltime
Auto-resubmit

```
#!/bin/bash
# Put your SLURM options here
#SBATCH --partition=debug           # change to proper partition name or remove
#SBATCH --time=00:00:30             # put proper time of reservation here
#SBATCH --nodes=1                   # number of nodes
#SBATCH --ntasks-per-node=1         # processes per node
#SBATCH --job-name="dmtcp_job"      # change to your job name
#SBATCH --output=slurm.dmtcp        # change to proper file name or remove for defaults
#SBATCH --signal=B:USR1@60
#SBATCH --open-mode=append
```

```
#####
# 1. Start DMTCP coordinator
#####

start_coordinator -i 10 # -i 120 ... <put dmtcp coordinator options here>

#####
# 2. Launch application
#####
echo "requeue #${SLURM_RESTART_COUNT}"

if [[ -e dmtcp_restart_script.sh && "${SLURM_RESTART_COUNT}" != "" ]]; then
    /bin/bash ./dmtcp_restart_script.sh -h $DMTCP_COORD_HOST -p $DMTCP_COORD_PORT &
else
    srun dmtcp_launch --allow-file-overwrite      python -u count-orig.py 10<&- 11>&- &
fi

#####
# 3. setup requeue for the wall time
# Note the #SBATCH --signal=B:USR1@60 which is needed
#####
timeout(){
echo "doing checkpoint"
dmtcp_command --bcheckpoint
sleep 2
echo "doing checkpoint; done"
dmtcp_command --quit
sleep 2
scontrol requeue $SLURM_JOB_ID
}

trap 'timeout' USR1
wait
```

Solution

Periodic checkpoint
Checkpoint at walltime
Auto-resubmit

```
#!/bin/bash
# Put your SLURM options here
#SBATCH --partition=debug          # change to proper partition name or remove
#SBATCH --time=00:00:30           # put proper time of reservation here
#SBATCH --nodes=1                 # number of nodes
#SBATCH --ntasks-per-node=1       # processes per node
#SBATCH --job-name="dmtcp_job"    # change to your job name
#SBATCH --output=slurm.dmtcp      # change to proper file name or remove for defaults
#SBATCH --signal=B:USR1@60
#SBATCH --open-mode=append
```

```
#####
# 1. Start DMTCP coordinator
#####

start_coordinator -i 10 # -i 120 ... <put dmtcp coordinator options here>

#####
# 2. Launch application
#####
echo "requeue #${SLURM_RESTART_COUNT}"

if [[ -e dmtcp_restart_script.sh && "${SLURM_RESTART_COUNT}" != "" ]]; then
    /bin/bash ./dmtcp_restart_script.sh -h $DMTCP_COORD_HOST -p $DMTCP_COORD_PORT &
else
    srun dmtcp_launch --allow-file-overwrite python -u count-orig.py 10<&- 11>& &
fi

#####
# 3. setup requeue for the wall time
# Note the #SBATCH --signal=B:USR1@60 which is needed
#####
timeout(){
    echo "doing checkpoint"
    dmtcp_command --bcheckpoint
    sleep 2
    echo "doing checkpoint; done"
    dmtcp_command --quit
    sleep 2
    scontrol requeue $SLURM_JOB_ID
}

trap 'timeout' USR1
wait
```

Demo #4

`slurm_dmtcp_solution.sub`



Summary, Wrap-up and Conclusions.

Never click 'Discard' again...

