XPFlow
(Experimental workflow)

Tomasz Buchert

Research in distributed systems

We all know how frustrating experimenting can be.

That's because experiments in distributed systems are:

- time-consuming
- difficult to do correctly
- complex and incomprehensible
- failure-prone

Automation of system administration

With tools like Chef and Puppet:

- a human factor is nearly removed
- systems are built from modules
- the configuration is reproducible

But reproducibility does not necessarily imply **descriptiveness**.
It does not imply **ease of understanding** either.

Experimentation tools

Many tools to manage experiments exist:

- Expo
- g5k-campaign
- OMF
- Plush
- ... among many others

They are based on different paradigms.

Bottom-up vs top-down approach

Most of these tools use **bottom-up design**.

What about a **top-down** approach?

1. Start with high-level description of the experiment.
2. Implement low-level details.
3. Run the experiment.
4. Improve if necessary and reiterate.

There already exists an approach like this.

Business Process Management

Business Process Management is about:

- understanding an organization
- modeling its processes as **workflows**
- **executing** processes and **monitoring** them
- **improving** organizational **activities**
- redesigning **processes** to make them:
  - cheaper
  - faster
  - less defective

XPFlow

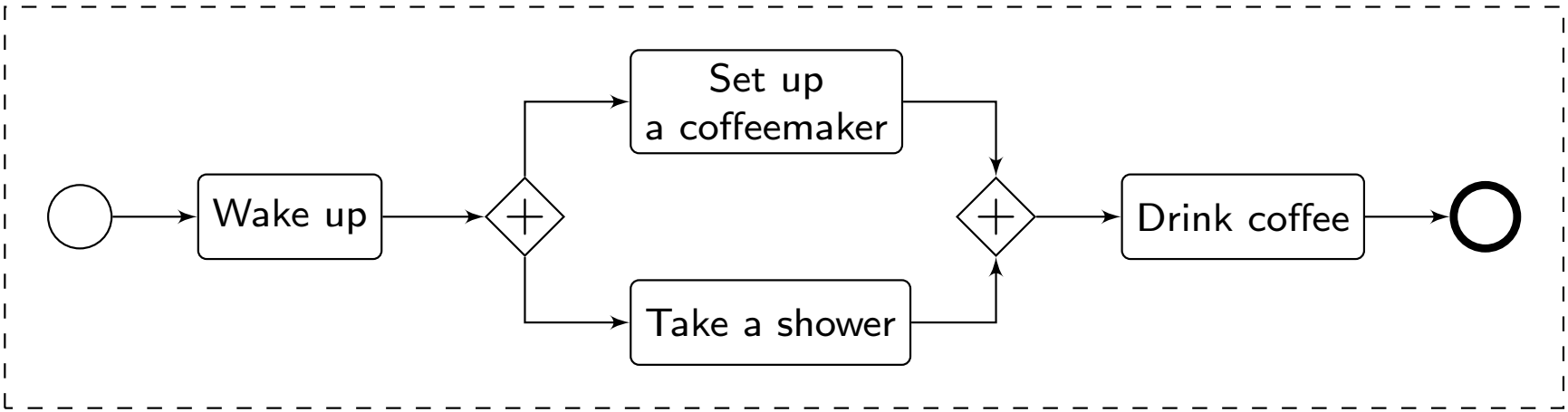
In this talk I will present **XPFlow**:

- a new experimentation engine
- based on **Business Process Modeling** and **Management**

XPFlow concepts

There are 2 main concepts in XPFlow:

- Processes – high-level description of an experiment:
  - workflows written in a DSL
  - orchestrate other processes and activities
- Activities – low-level building blocks of experiments:
  - do real hard work
  - written in Ruby



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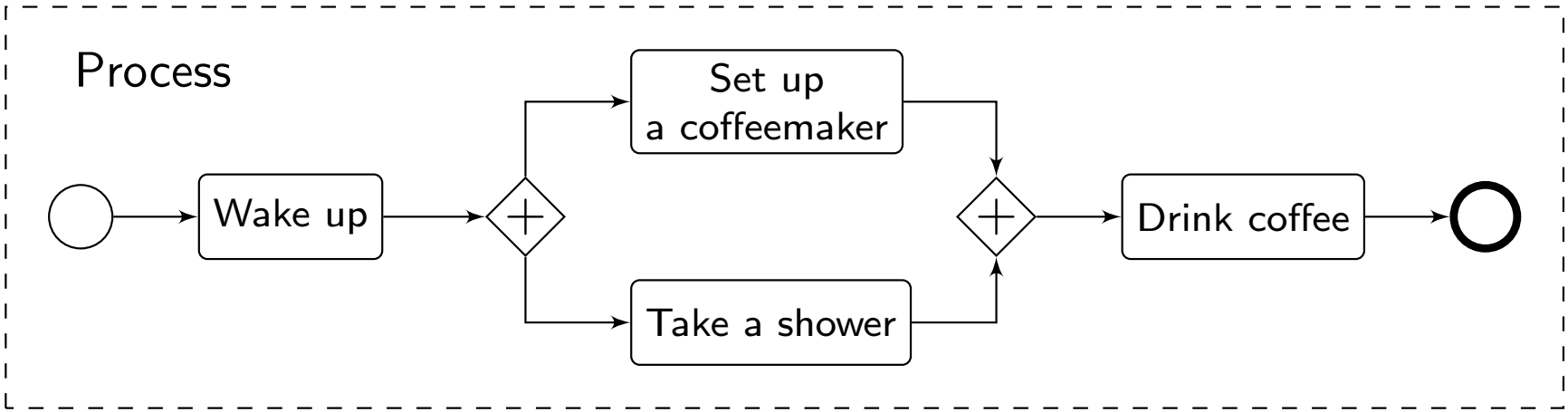

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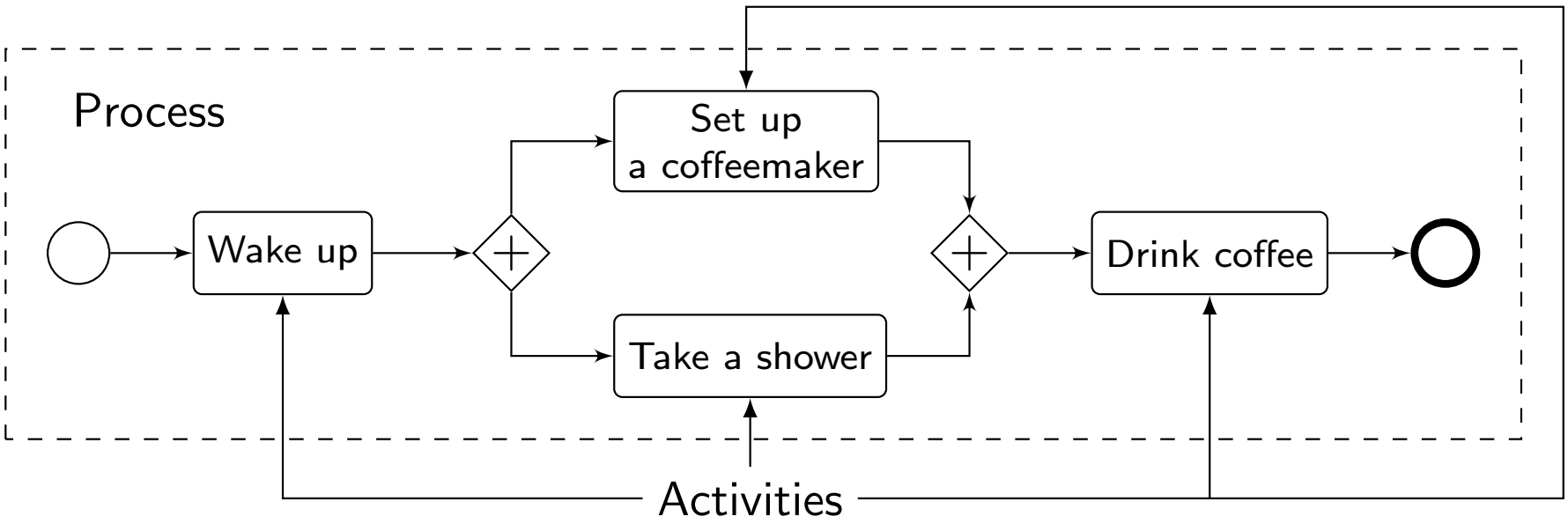


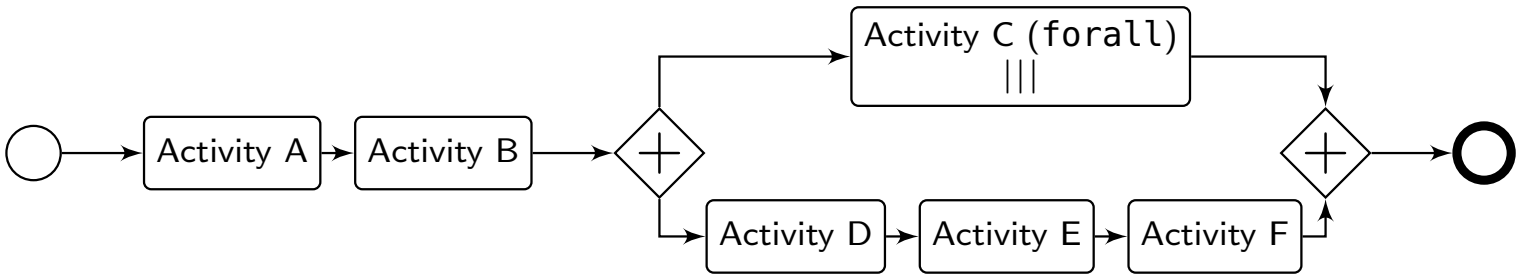
Domain-specific language for processes

The DSL for processes features different **workflow patterns**:

- running activities and other processes (`run`),
- running activities in order or in parallel (`sequence`, `parallel`),
- conditional expressions (`if`, `switch`)
- running sequential and parallel loops (`loop`, `foreach`, `forall`),
- error handling (`try`, `checkpoint`).

Some of them are taken directly from BPM.

Workflow patterns (example)



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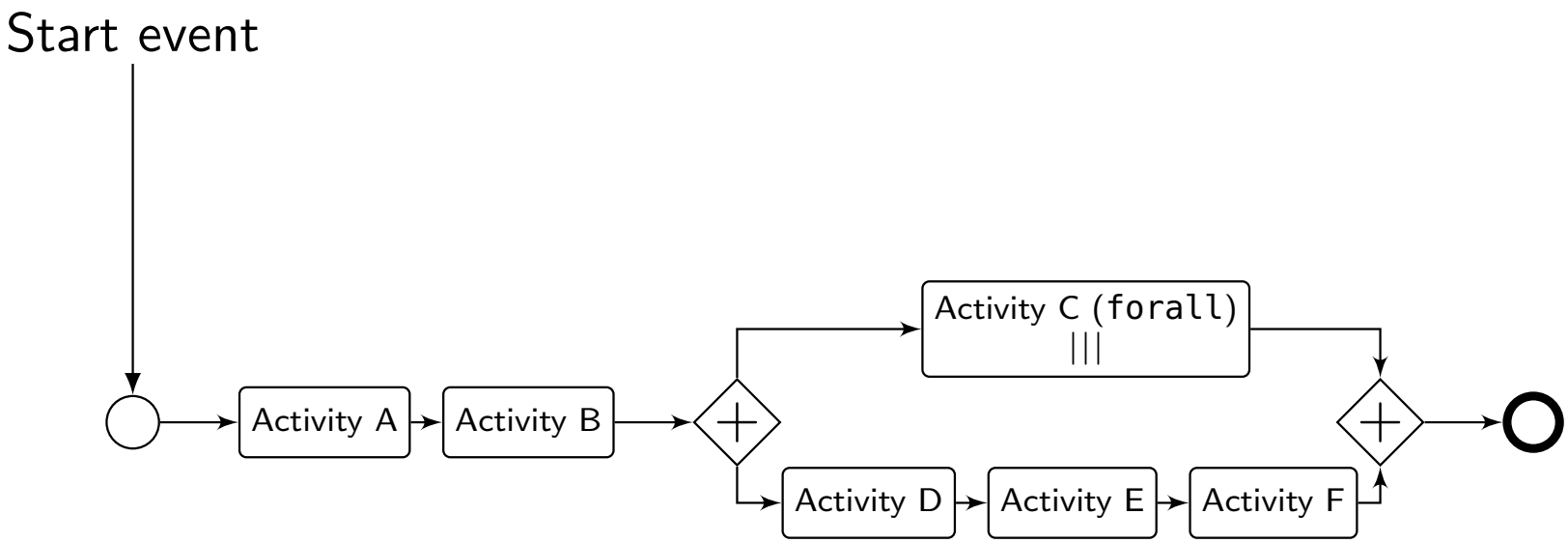

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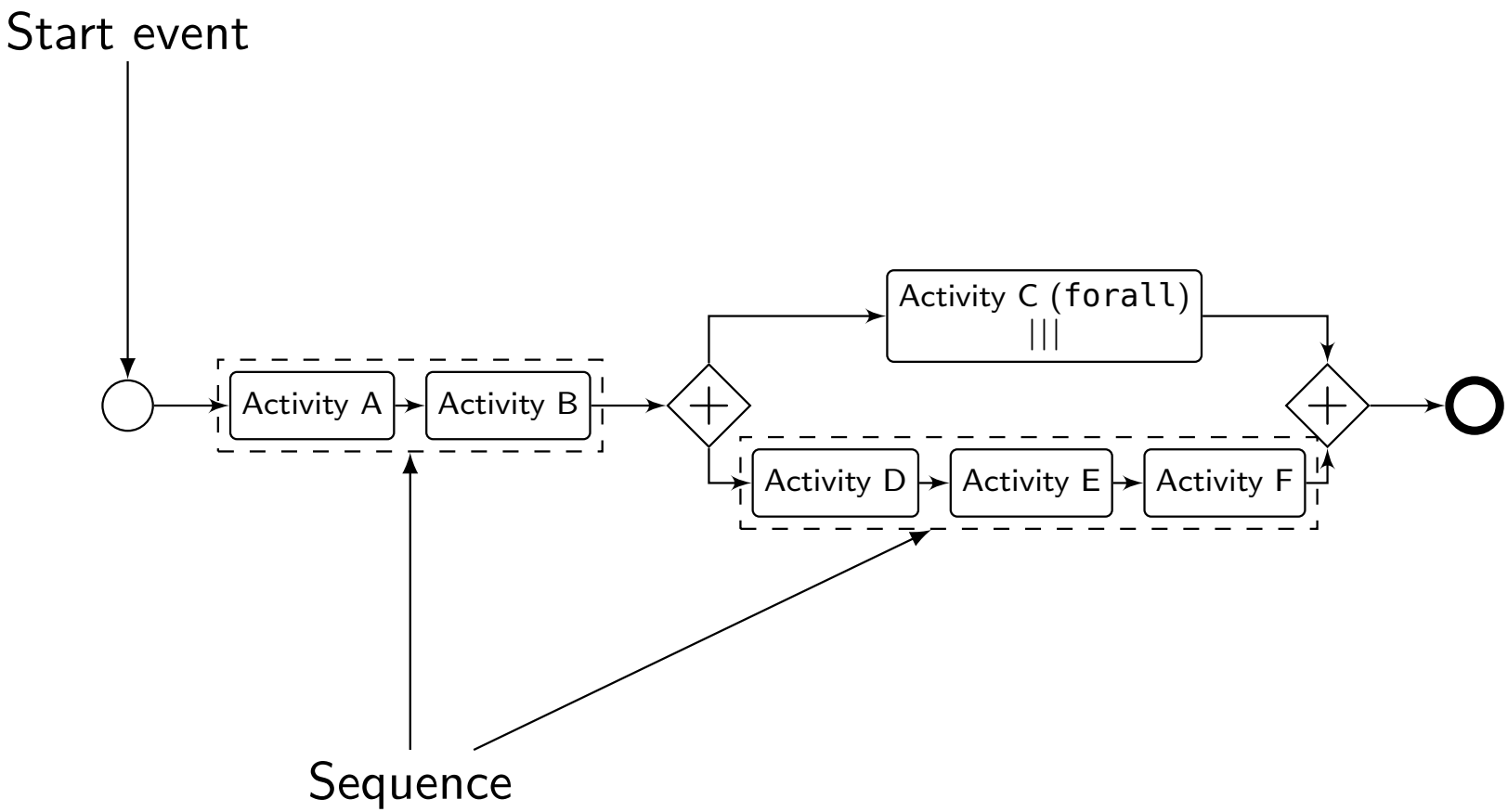

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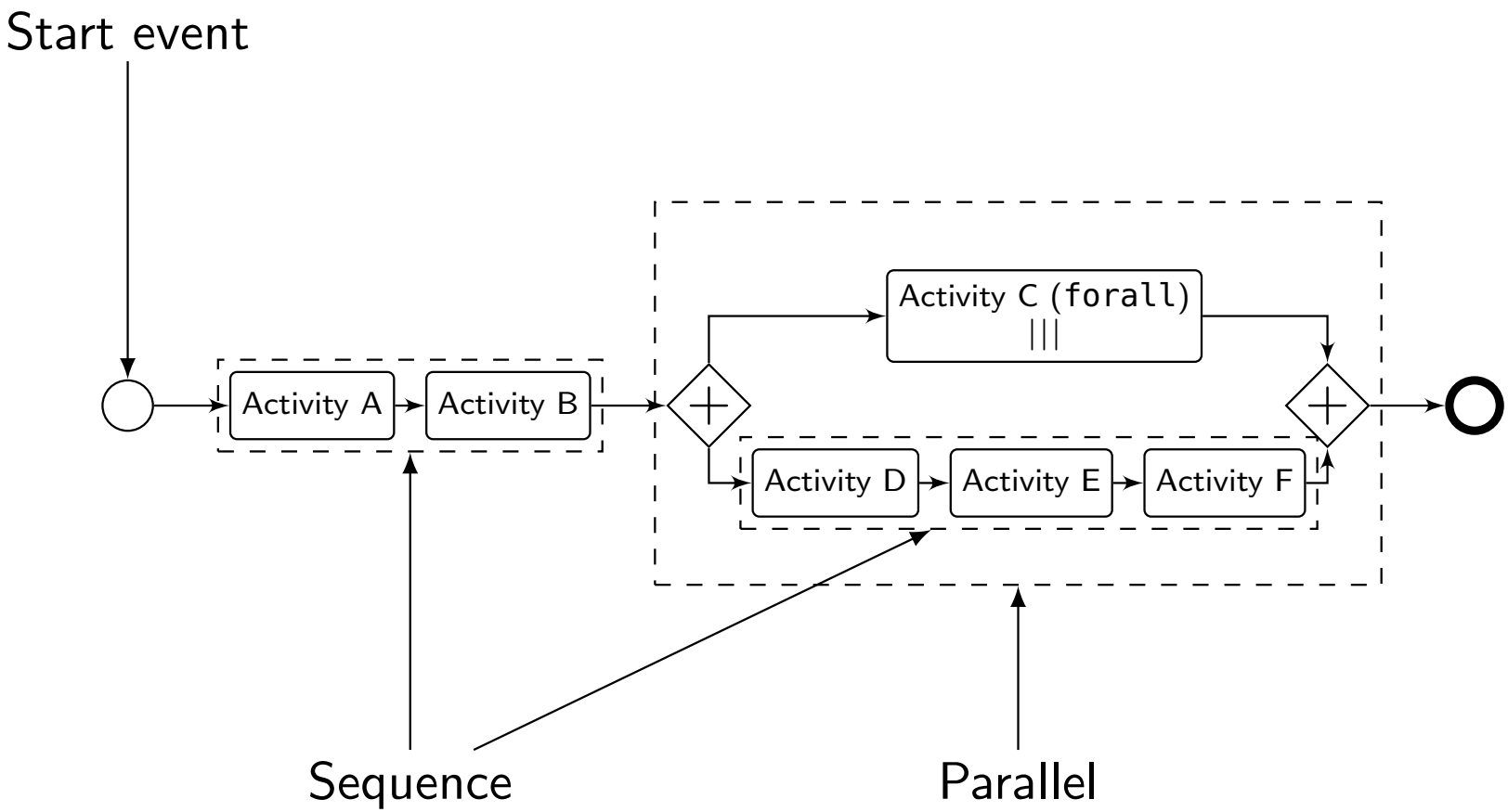

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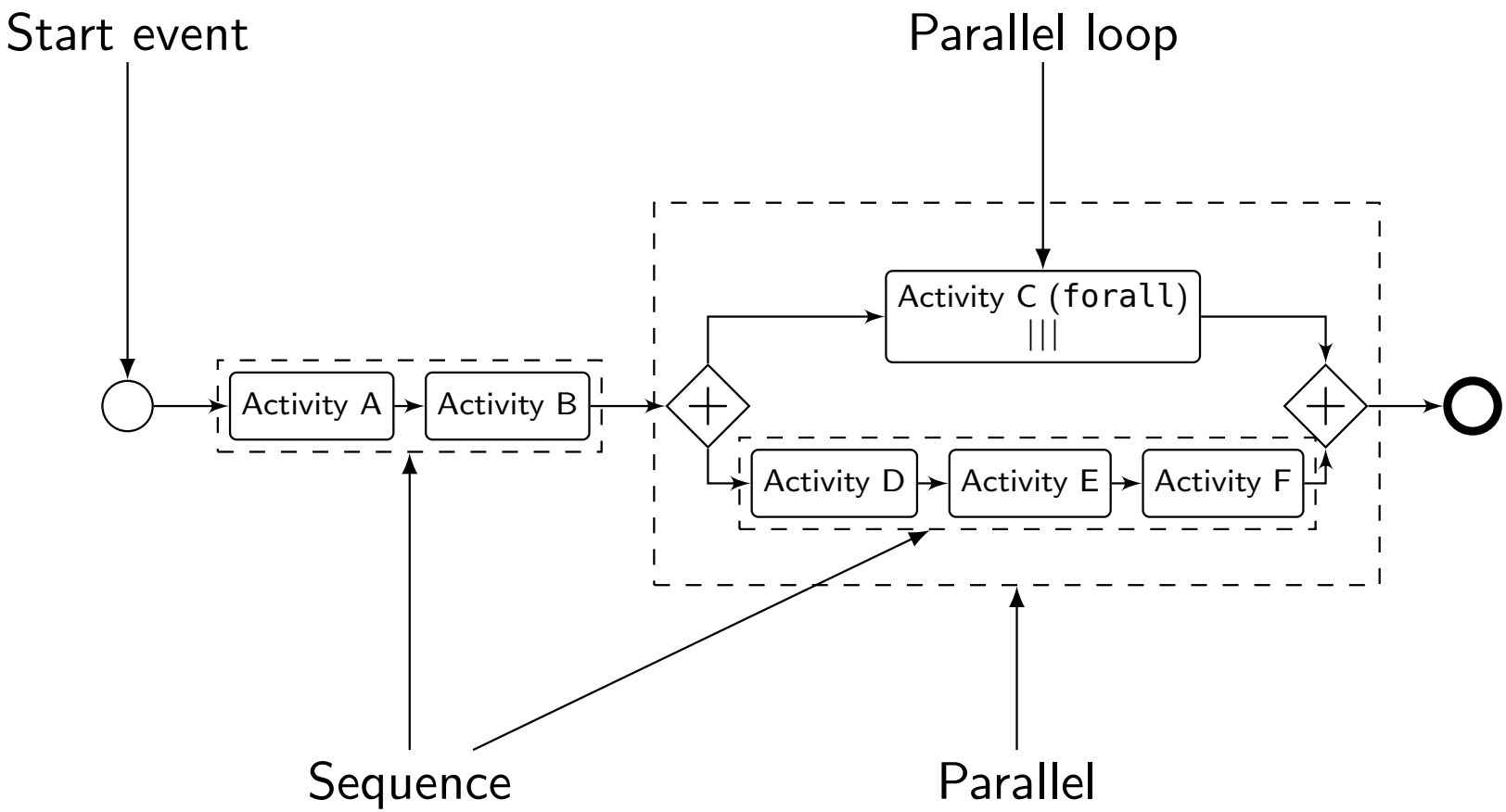

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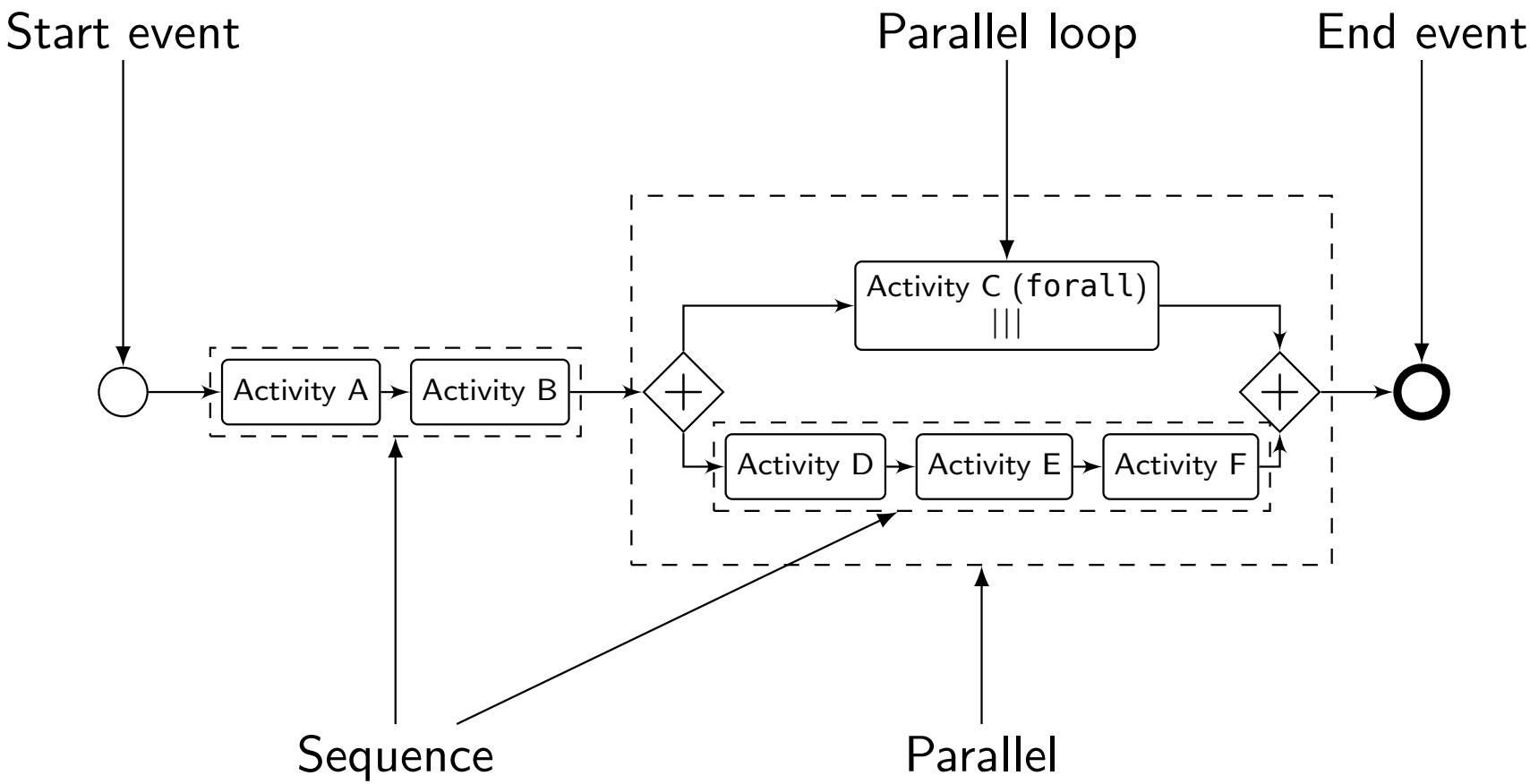

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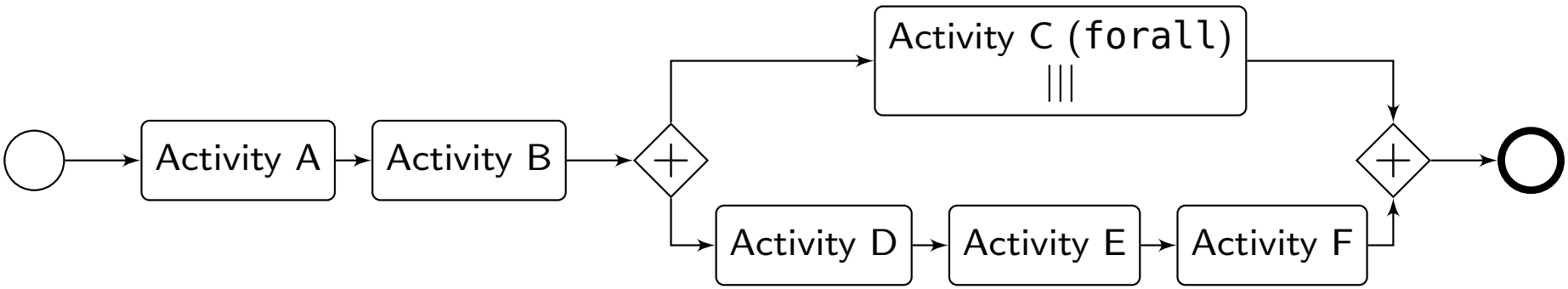


```
process :workflow do |array|
    run :a
    run :b
    parallel do
        forall array do |x|
            run :c, x
        end
        sequence do
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        end
    end
end
```

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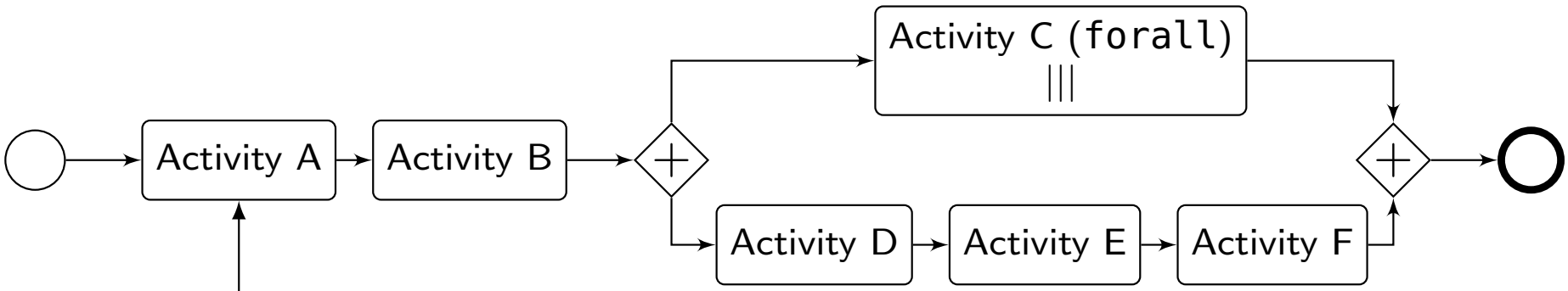


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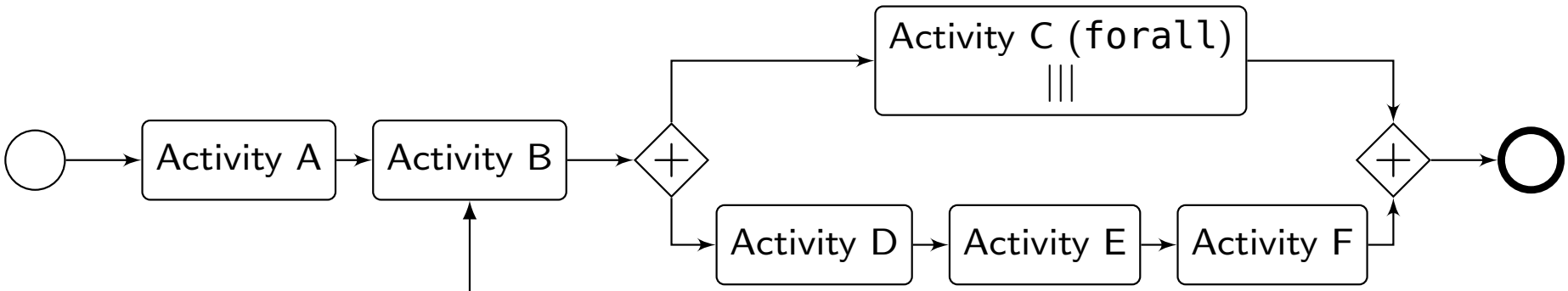


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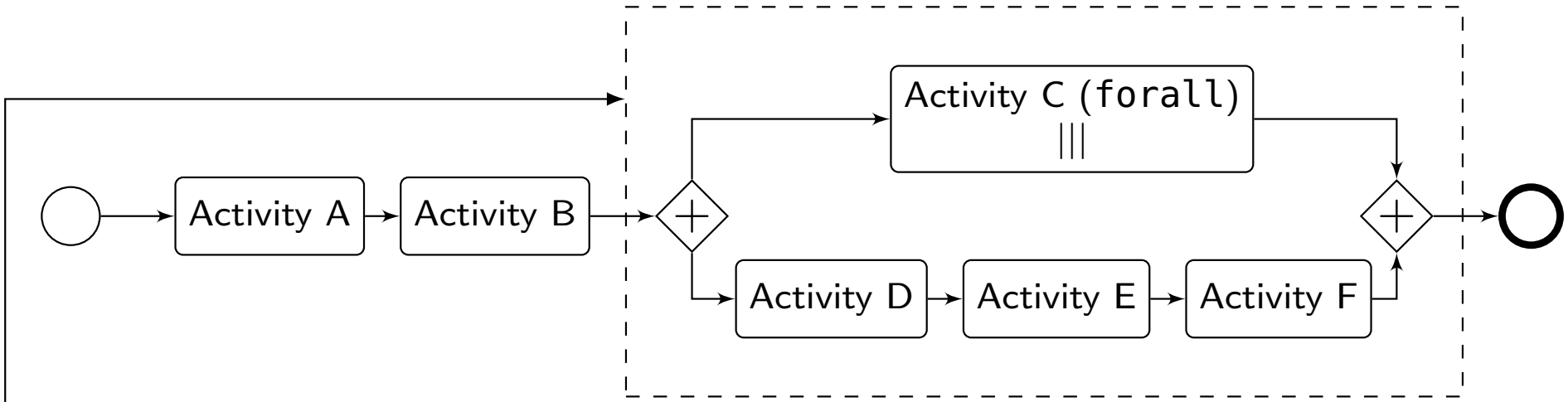


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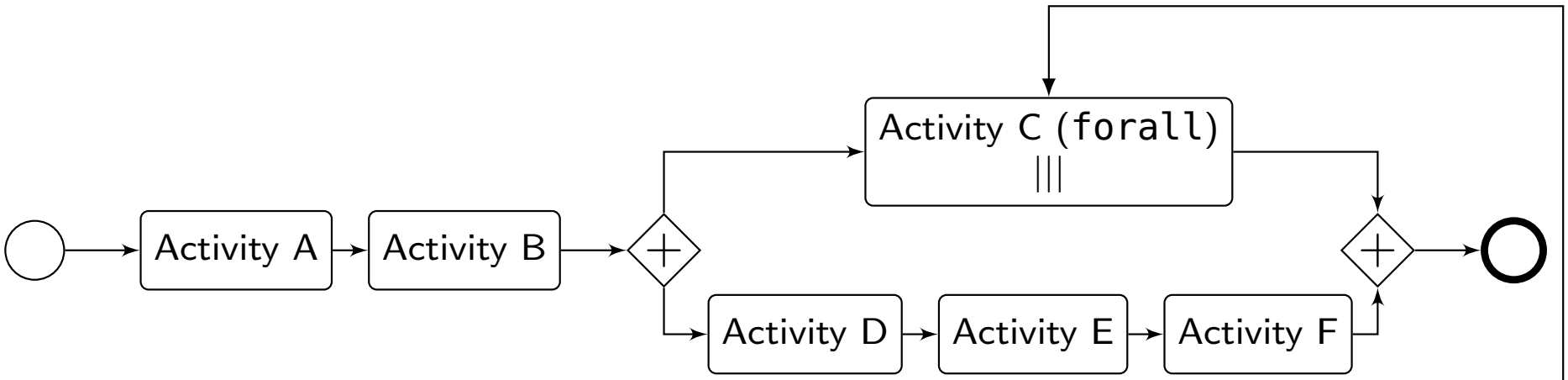


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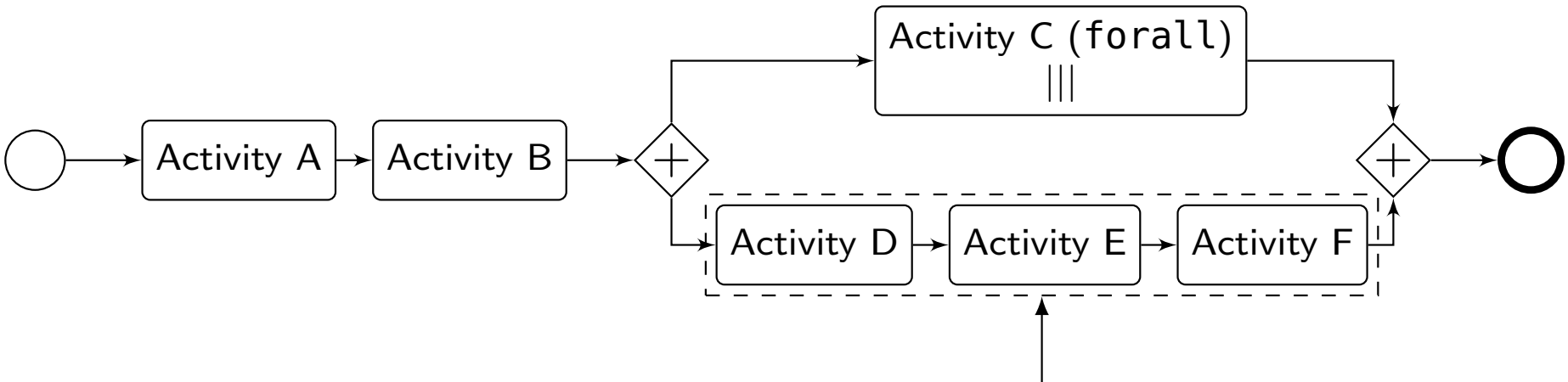


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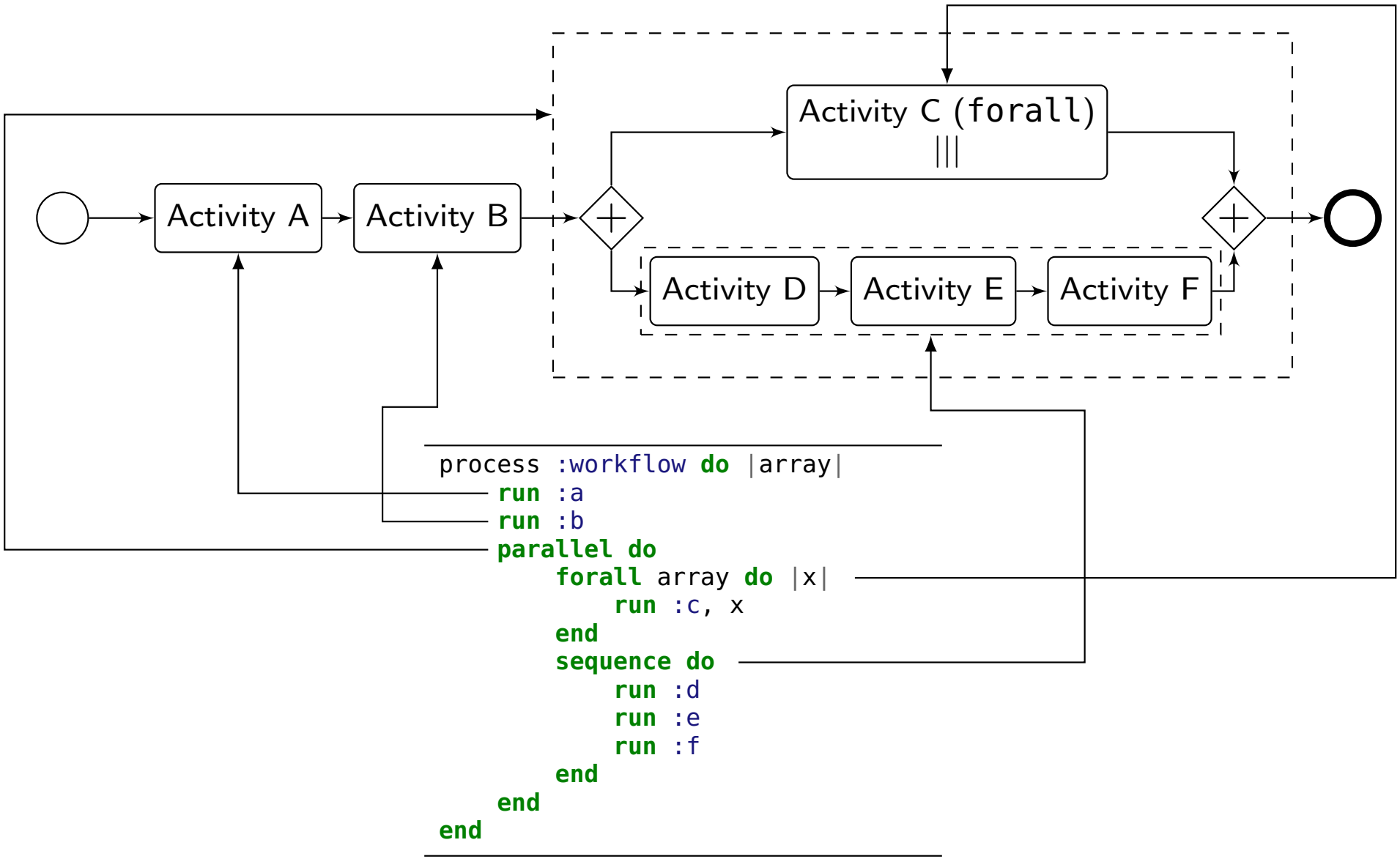


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            run :c, x
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        sequence do
            run :d
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            run :f
        end
    end
end
```

Minimal Grid'5000 example

```
#!/usr/bin/env xpflow

use :g5k

process :clean_all do
    sites = run :g5k.sites
    forall sites do |s|
        jobs = run :g5k.my_jobs, s
        log "Cleaning ", s, " from ", (length_of jobs), " jobs..."
        run :g5k.release_all, s
    end
end

main :clean_all
```

Assumes that `xpflow` is in your `$PATH`.

Slightly less minimal Grid'5000 example

```
#!/usr/bin/env xpflow

use :g5k

process :build_kernel do |sources|
    run :ensure_exists, sources
    r = run :g5k.reserve_nodes,
        :nodes => 1,
        :time => '1h',
        :site => 'nancy'
    nodes = run :g5k.nodes, r
    node = (first_of nodes)
    checkpoint :reserved
    log 'Our node is: ', node
    run :copy_sources,
        sources, node
    checkpoint :source_copied
    run :make_kernel, node
    checkpoint :kernel_made
    run :copy_debs, node
    run :g5k.release, r
end

main :build_kernel, :str
```

```
activity :copy_sources do |sources, node|
    run 'g5k.copy', sources,
        node, '/tmp/linux.tar.gz'
    run 'g5k.bash', node do
        cd '/tmp'
        run 'rm -rf linux-build'
        make_dirs 'linux-build'
        untar 'linux.tar.gz',
              'linux-build'
    end
end

activity :make_kernel do |node|
    run 'g5k.bash', node do
        cd '/tmp/linux-build'
        cd dirs.first
        run 'make deb-pkg -j 5'
    end
end

activity :copy_debs do |node|
    run 'g5k.retrieve', node,
        '/tmp/linux-build/*.deb'
    run 'g5k.bash', node do
        run 'rm -rf /tmp/linux-build'
    end
end
```

Error handling

XPFlow gives some means to cope with failures:

- snapshotting:
  - saves a state of an experiment for future use
  - shortens a development's cycle
- retry policy:
  - retries a failed subprocess execution
  - improves reliability

```
process :snapshotting do
    run :long_deployment
    checkpoint :d
    run :experiment
end
```

```
process :retrying do
    try :retry => 5 do
        run :tricky_activity
    end
end
```

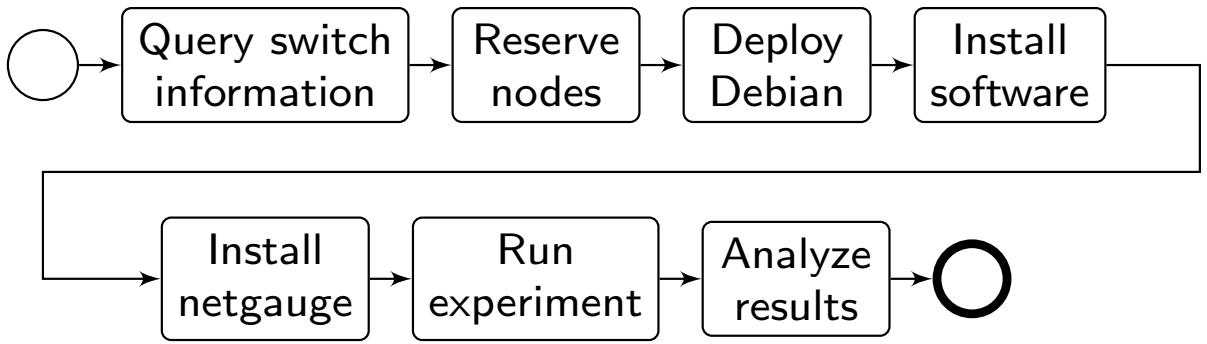
Both features require **idempotency**.

Example of an experiment

Measure the *effective bisection bandwidth* of a switch.

1. Get names of all nodes connected to the switch.
2. Reserve the nodes.
3. Deploy Debian OS.
4. Install necessary software.
5. Compile and install *netgauge*.
6. Run the experiment.
7. Analyze results.

An experiment workflow

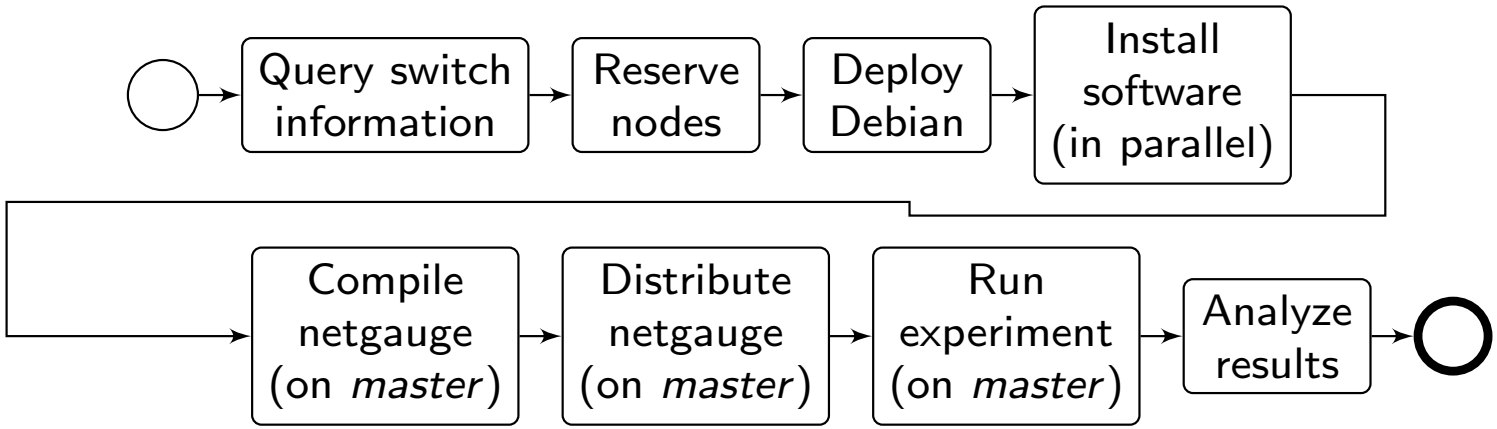


Few notes:

- each node must have some software installed
- each node must have *netgauge* installed ...
- ... but one node is enough to compile it
- one node must launch MPI application

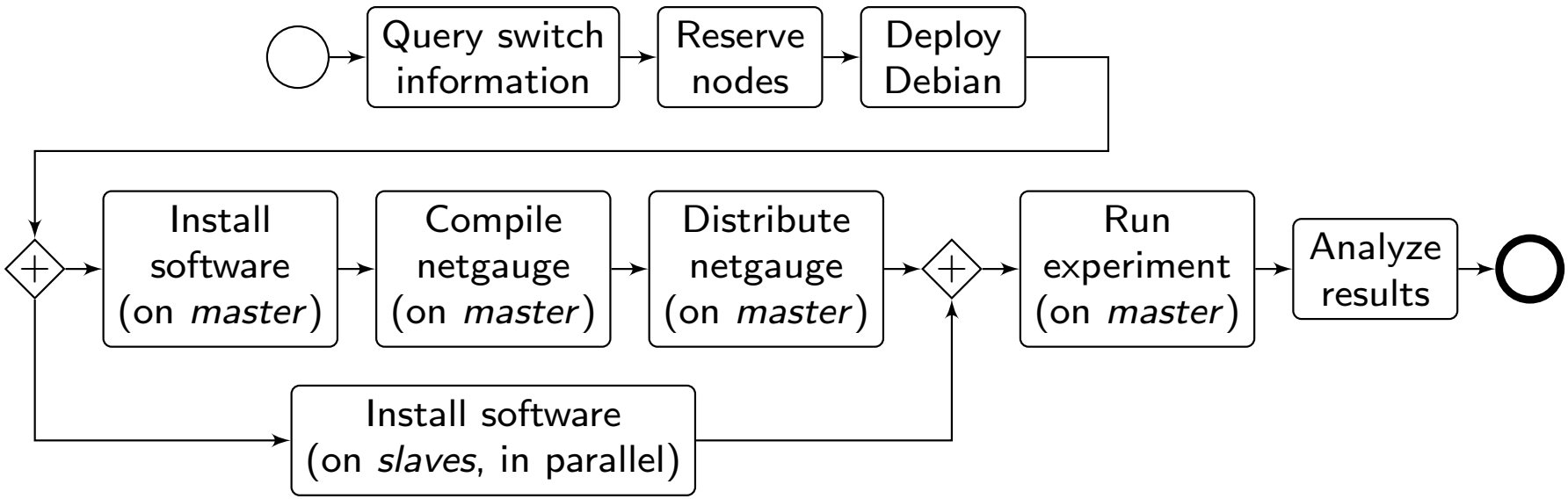
We will introduce a *master* node and *slave* nodes.

An experiment workflow



Another observation: compilation can run in parallel with installation of software on the *slave* nodes.

An experiment workflow



This workflow describes our experiment.
The last thing to do is to express that in XPFlow.

An experiment workflow - DSL representation

```
process :exp do |site, switch|
    s = run g5k.switch, site, switch
    ns = run g5k.nodes, s
    r = run g5k.reserve_nodes,
        :nodes => ns, :time => '2h',
        :site => site, :type => :deploy
    master = (first_of ns)
    rest = (tail_of ns)
    run g5k.deploy,
        r, :env => 'squeeze-x64-nfs'
    checkpoint :deployed
    parallel :retry => true do
        forall rest do |slave|
            run :install_pkgs, slave
        end
        sequence do
            run :install_pkgs, master
            run :build_netgauge, master
            run :dist_netgauge,
                master, rest
        end
    end
    checkpoint :prepared
    output = run :netgauge, master, ns
    checkpoint :finished
    run :analysis, output, switch
end
```

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        end
    end
    checkpoint :prepared
    output = run :netgauge, master, ns
    checkpoint :finished
    run :analysis, output, switch
end
```

Activity `:install_pkgs`

```
activity :install_pkgs do|node|
    log 'Installing packages on ', node
    run 'g5k.bash', node do
        aptget :update
        aptget :upgrade
        aptget :purge, 'mx'
    end
end
```

An experiment workflow - DSL representation

```
process :exp do |site, switch|
    s = run g5k.switch, site, switch
    ns = run g5k.nodes, s
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end
```

Activity :build_netgauge

```
activity :build_netgauge do |master|
    log "Building netgauge on #{master}"
    run 'g5k.copy', NETGAUGE, master, '~'
    run 'g5k.bash', master do
        build_tarball NETGAUGE, PATH
    end
    log "Build finished."
end
```

An experiment workflow - DSL representation

```
process :exp do |site, switch|
    s = run g5k.switch, site, switch
    ns = run g5k.nodes, s
    r = run g5k.reserve_nodes,
        :nodes => ns, :time => '2h',
        :site => site, :type => :deploy
    master = (first_of ns)
    rest = (tail_of ns)
    run g5k.deploy,
        r, :env => 'squeeze-x64-nfs'
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    parallel :retry => true do
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        end
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            run :build_netgauge, master
            run :dist_netgauge,
                master, rest
        end
    end
    checkpoint :prepared
    output = run :netgauge, master, ns
    checkpoint :finished
    run :analysis, output, switch
end
```

Activity :dist_netgauge

```
activity :dist_netgauge do |m, s|
    master, slaves = m, s
    run 'g5k.dist_keys', master, slaves
    run 'g5k.bash', master do
        distribute BINARY,
            DEST, 'localhost', slaves
    end
end
```

An experiment workflow - DSL representation

```
process :exp do |site, switch|
    s = run g5k.switch, site, switch
    ns = run g5k.nodes, s
    r = run g5k.reserve_nodes,
        :nodes => ns, :time => '2h',
        :site => site, :type => :deploy
    master = (first_of ns)
    rest = (tail_of ns)
    run g5k.deploy,
        r, :env => 'squeeze-x64-nfs'
    checkpoint :deployed
    parallel :retry => true do
        forall rest do |slave|
            run :install_pkgs, slave
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            run :dist_netgauge,
                master, rest
        end
    end
    checkpoint :prepared
    output = run :netgauge, master, ns
    checkpoint :finished
    run :analysis, output, switch
end
```

Activity :netgauge

```
activity :netgauge do |master, nodes|
    log "Running experiment..."
    out = run 'g5k.bash', master do
        cd PATH
        mpirun nodes, "./netgauge"
    end
    log "Experiment done."
end
```

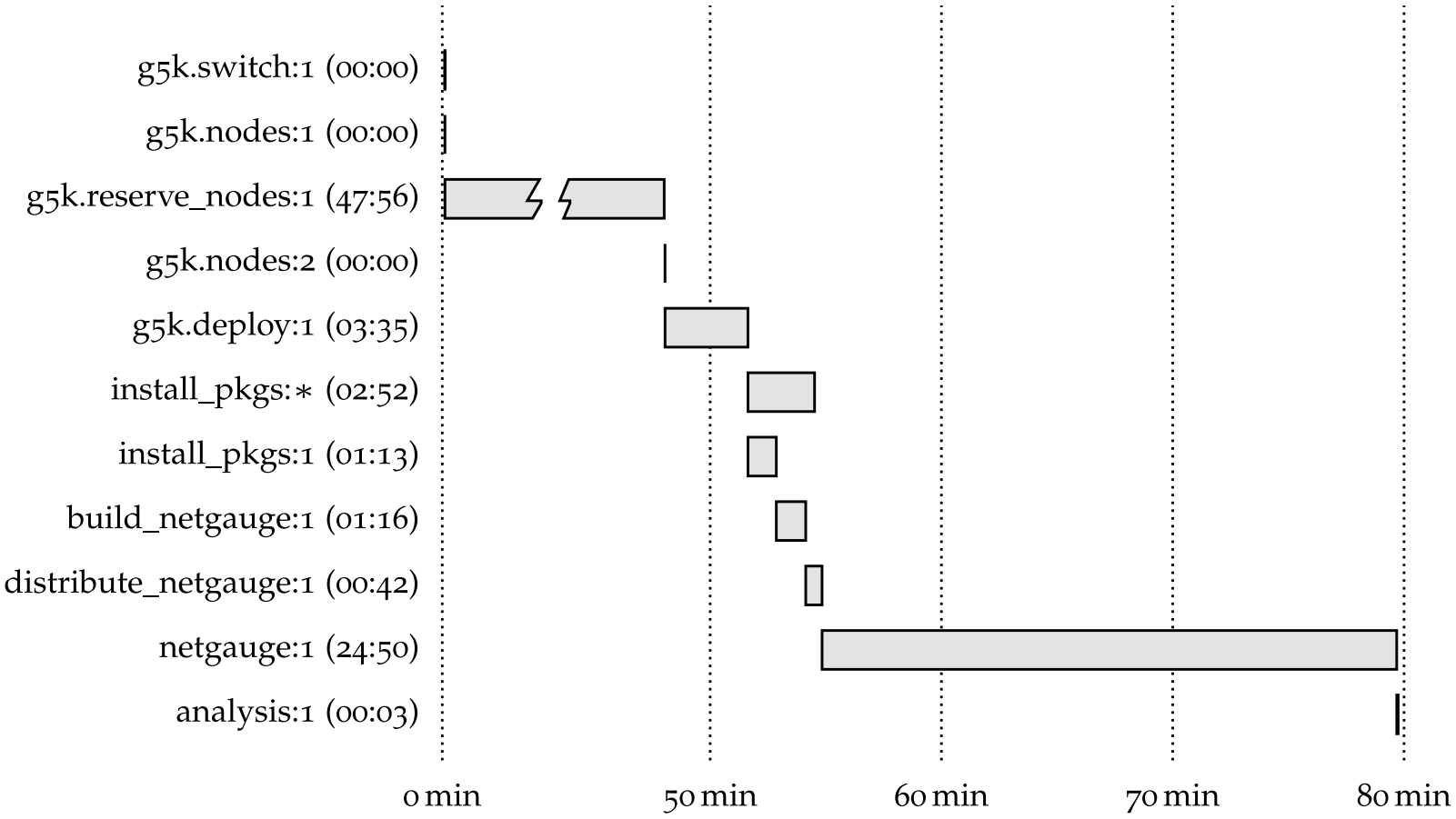
Running the experiment

The experiment runs on Grid'5000 frontend or on your local machine.

```
[ 11:15:52.940 ] Started activity g5k.switch:1.
[ 11:15:53.418 ] Finished activity g5k.switch:1 (0.478 s).
[ 11:15:53.419 ] Process exp: Experimenting with switch: sgraphene2
[ 11:15:53.419 ] Started activity g5k.nodes:1.
[ 11:15:53.419 ] Finished activity g5k.nodes:1 (0.000 s).
[ 11:15:53.419 ] Started activity g5k.reserve_nodes:1.
[ 11:15:55.837 ] Waiting for reservation 408387
[ 11:16:02.452 ] Reservation 408387 should be available in 12 mins
[ 11:16:02.452 ] Reservation 408387 ready
[ 11:16:02.453 ] Finished activity g5k.reserve_nodes:1 (9.022 s).
[ 11:16:02.453 ] Started activity g5k.nodes:2.
[ 11:16:02.453 ] Finished activity g5k.nodes:2 (0.000 s).
[ 11:16:02.453 ] Started activity g5k.deploy:1.
[ 11:22:09.427 ] Finished activity g5k.deploy:1 (366.968 s).
[ 11:22:09.429 ] Started activity install_pkgs.
[ 11:22:09.429 ] Started activity install_pkgs:1.
[ 11:22:09.430 ] Activity install_pkgs: Installing packages on graphene-96
[ 11:22:09.430 ] Started activity install_pkgs:2.
[ 11:22:09.430 ] Activity install_pkgs: Installing packages on graphene-60
```

The execution is monitored and errors reported if necessary.

Monitoring features - Gantt chart of the execution



Each activity is monitored during its execution.

Notice that `build_netgauge:1` runs in parallel with `install_pkgs:*`.

To-do list

Features to implement:

- GUI to see progress and monitor
- workflow validation (using type checking)
- support for other testbed
- expressing G5K interface using workflows
- result/data provenance
- distributed workflows
- efficient operations
- improved modularity
- monitoring of the platform
- tutorial :)

Conclusions

In this talk I presented XPFlow.

Current features include:

- improved descriptiveness
- modularity and flexibility
- monitoring and support for common patterns
- integration with Grid'5000

In the future we will work on:

- integration with experimentation tools
- human interaction during the experiment
- efficient data broadcast and collection

Thank you for your attention. Questions?

Technicalities

XPFlow technical thingies:

- limitations of Ruby language (own language?)
- Ruby version hell
- access from outside G5K (also from Jenkins)
- repository at gforge (private, though)
- Jenkins at `http://ci.inria.fr` (Q: how to test?)

Ideas/problems slide

What about:

- treating everything as *actors* (or interfaces)?
- using functional programming to model experiments?
- having a virtual testbed?
- having an interactive mode?

Problems:

- "nested experimentation" (G5K → Distem → Exp)
- duplicated code
- many small problems
- ???

Demo?

Care for demo?