TakTuk,
Adaptive Deployment of Remote Executions

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Problem statement and Terms definition

The goal is to execute :

```
Foreach host in list_of_hosts do
   ssh $host some_command
```

Where :

- Remote executions are independent :
  parallel remote executions
- Either "root" or any of "list_of_hosts" can execute the ssh :
  deployment of remote execution tasks

Why parallel remote executions ?

Nodes administration:
run the same command on all nodes of a platform

- `uptime` to grab statistics about the recent machine availability
- `dig`, `ping`, `ifconfig` ... for network issues diagnostic
- ...

Parallel applications execution:
run the same executable on all nodes (`mpirun` does that)

- Slaves of a master/slave application
- All participants of a symmetric parallel application
- Self organizing system (P2P), daemons (monitoring)
- ...

very frequent during **applications development**

Needs

Transparency:
User should not have to worry about execution mechanics

- Automatization of remote connections to all the machines
- I/O multiplexing to the root node (gathering of result)
- ... whatever the target platform (cluster, grid, ...)

Efficiency:
Administration and applications development are interactive tasks

- Time to deploy is critical
- Management of all the nodes has to scale
- ...

Questions addressed in this talk

How to perform efficiently all the remote connections ?

- Parallelization ?
- Distribution ?

How to address heterogeneity ?

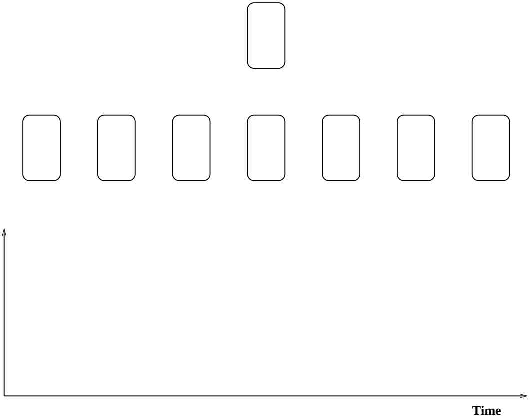
- Adaptivity ?
- Assume some configuration on nodes ?

Outline

1. Motivations
   - Problem
   - Needs
2. Deployment
   - Parallelization
   - Distribution
   - Optimal
3. TakTuk
   - Engine
   - Performance
   - Perspectives

Example of trivial solution

```
Foreach i in hosts do ssh $i uptime
```



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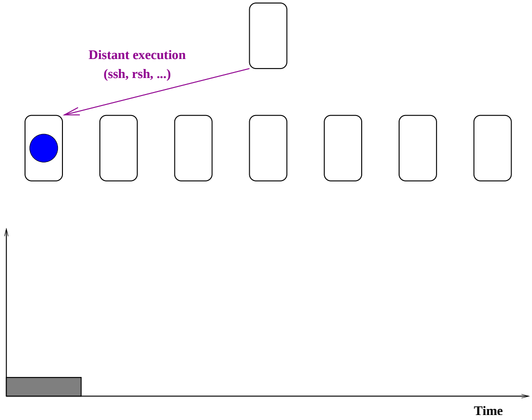

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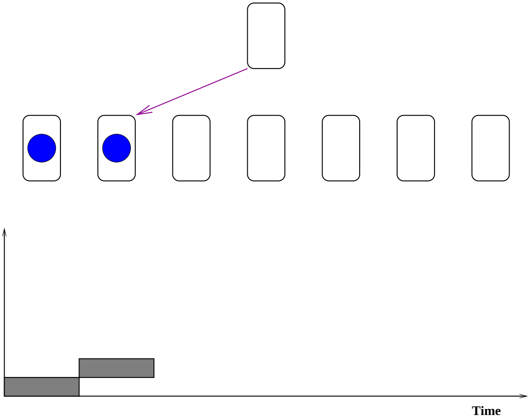

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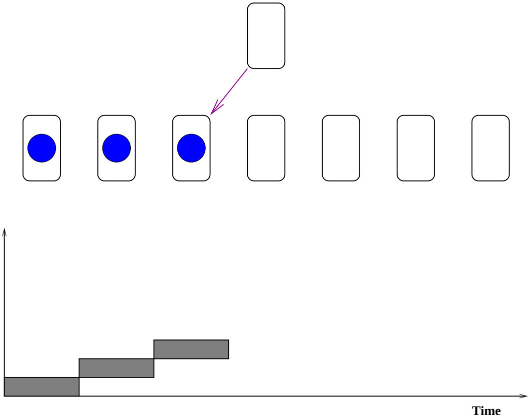

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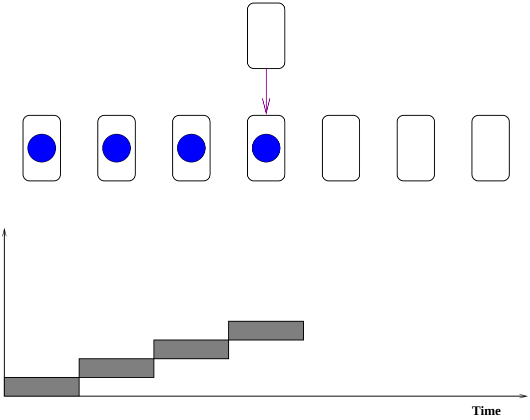

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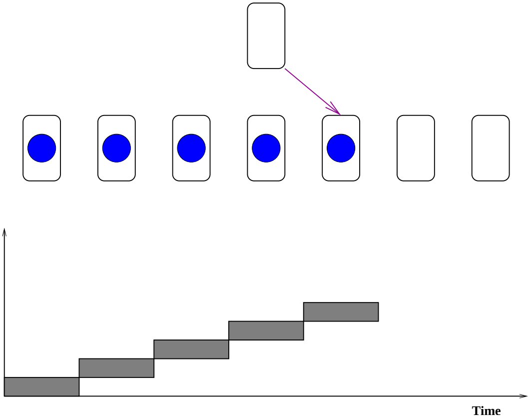

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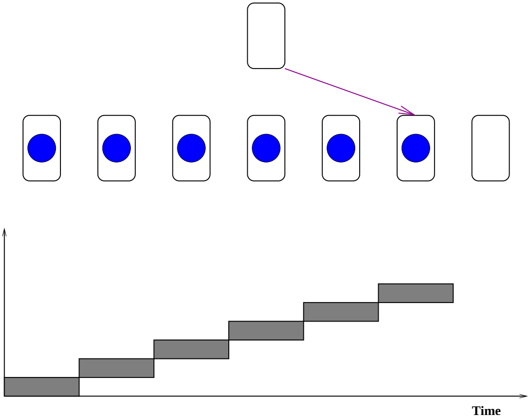

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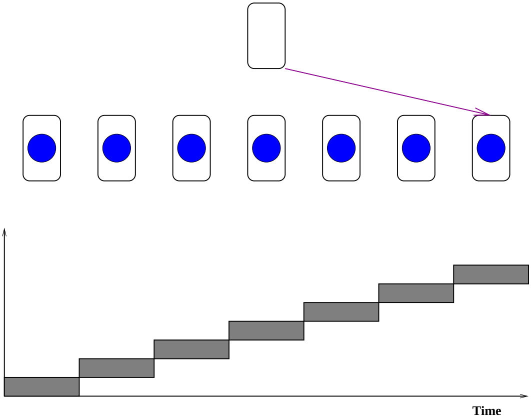

ssh takes about:
$100ms$
Execution time:
$n \times 100ms$
For 1000 nodes:
$1mn40$

Optimization seems simple

The deployment is embarrassingly parallel

- Just create one process (or thread) for each `ssh`
- All the connections will be initiated in parallel

..but reality is more complex than this

Local parallelization naturally pipelined by the scheduler

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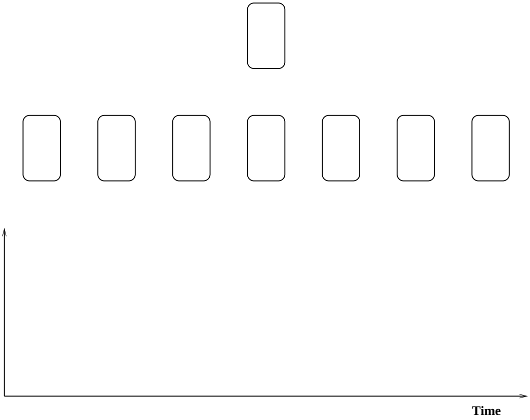
Foreach i in hosts do fork ssh $i uptime
```



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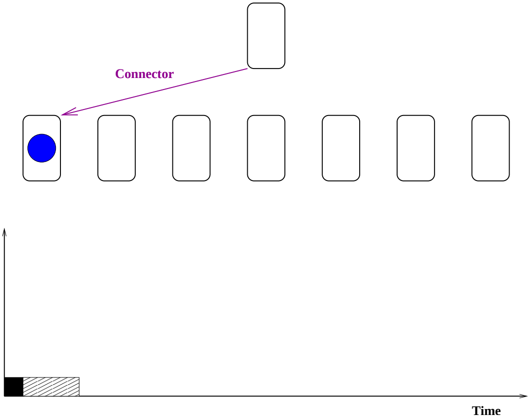

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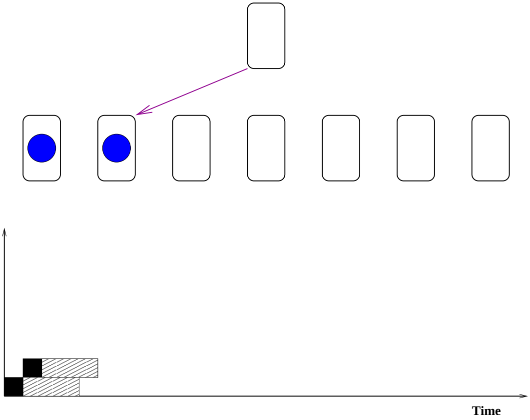

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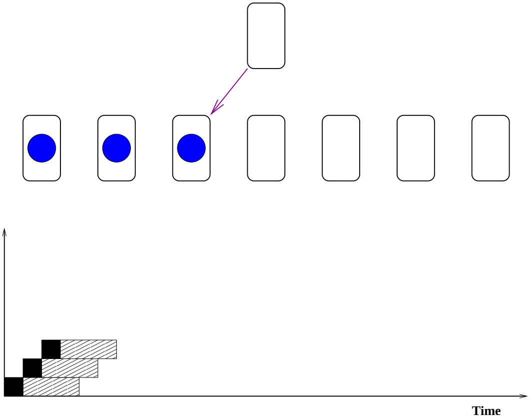

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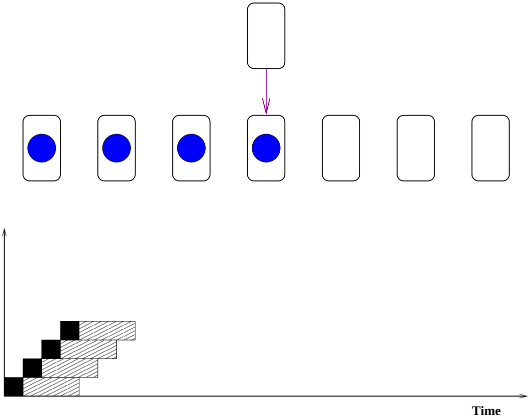

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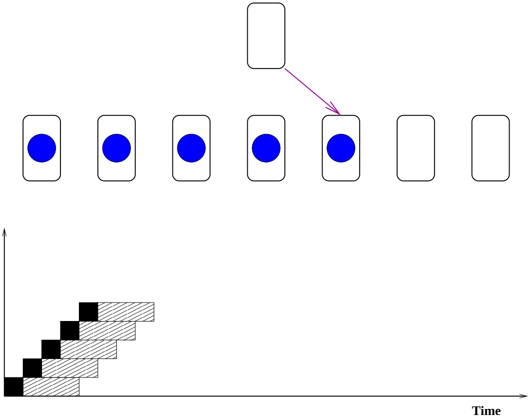

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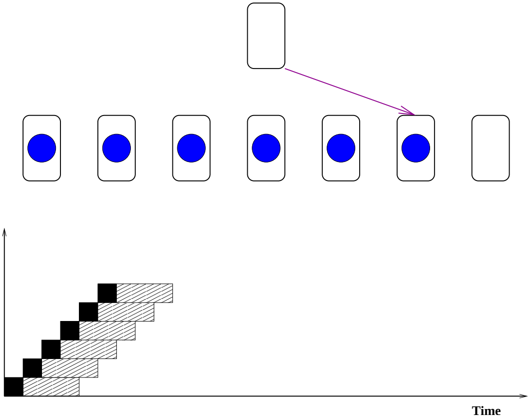

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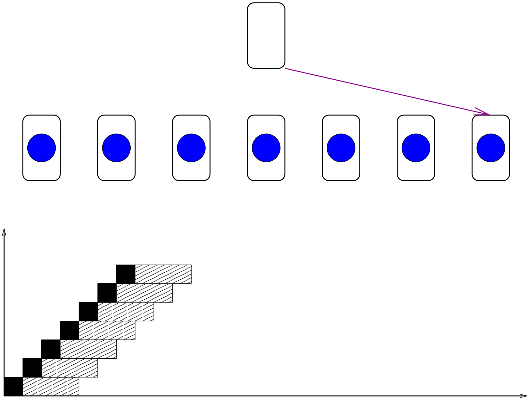


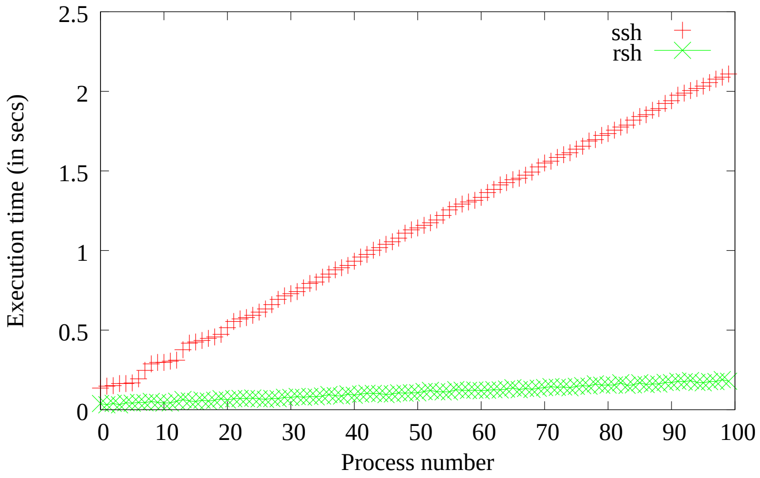
`ssh` pipeline shift: $20ms$

Execution time: $n \times 20ms + 80ms$

For 1000 nodes: $\simeq 20s$

Gain is about $100/20 = 5$ (constant factor)

Experiment with 100 connections run in parallel



How to further optimize the deployment ?

Issues

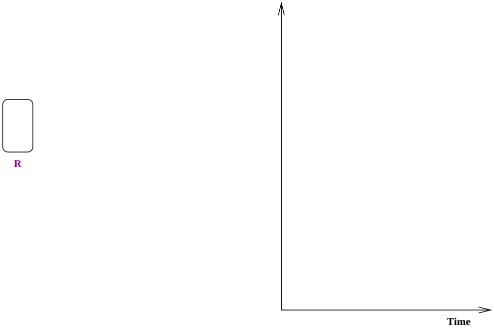
- Cost of **local parallelization** still **linear**
- The initiating machine is a critical resource:
  maximal number of processes, number of opened fds, ...

But we can make use of distribution

- Remote execution of the deployment engine itself
- Distant node take part of the deployment process
- The deployment engine has to multiplex and redirect I/Os

Work distribution

```
while remaining hosts do
      choose i in hosts
      ssh $i taktuk_engine(part(hosts))
taktuk_exec uptime
```



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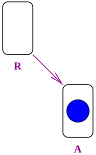

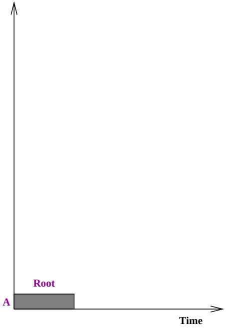

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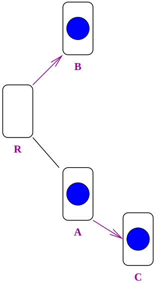

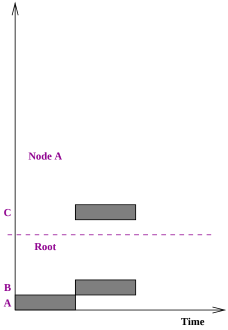

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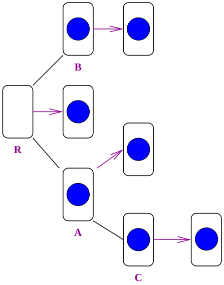
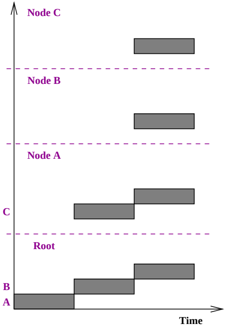
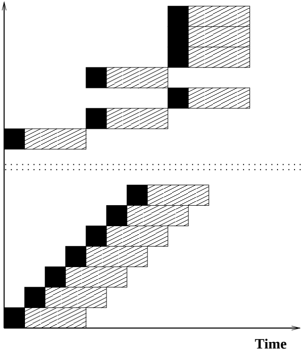


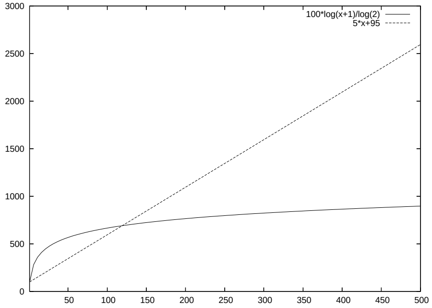


Deployment using a binomial tree
Execution time: $\log_2(n) \times 100ms$
For 1000 nodes: $1s$
without overhead of the engine
Gain: Logarithmic factor

Is work distribution optimal ?

Obviously not, for small node counts

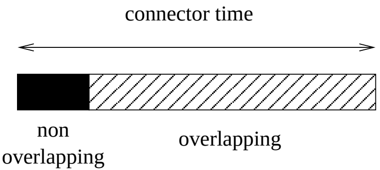




Connector model

A connector (`ssh`) can be abstracted by 2 parts

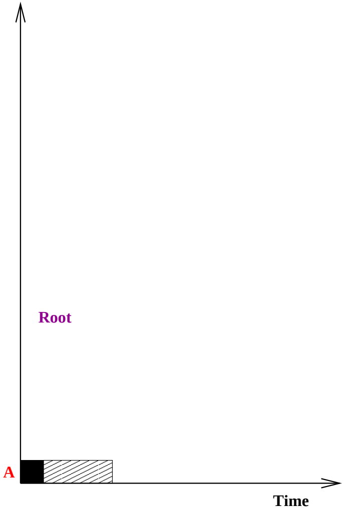
- Non overlapping part (protocol computation)
- Overlapping part (wait)



Similar to the postal model

- Homogeneous case known in the literature:
  ASAP is an **optimal** schedule
- Polynomially computable by a greedy algorithm

Optimal deployment



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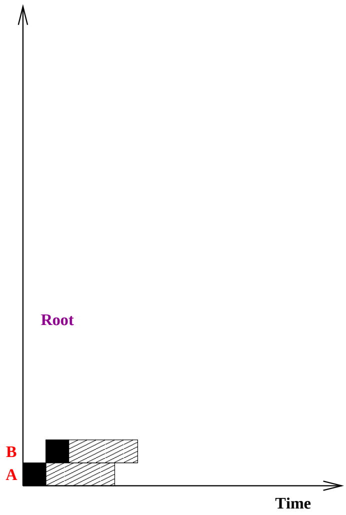

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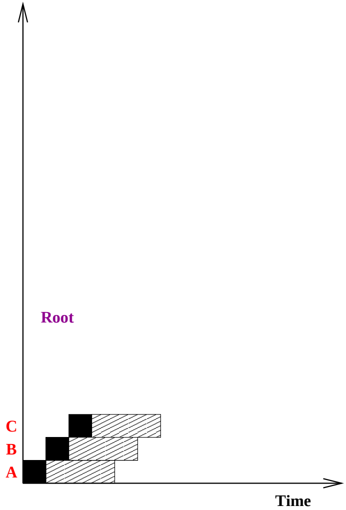

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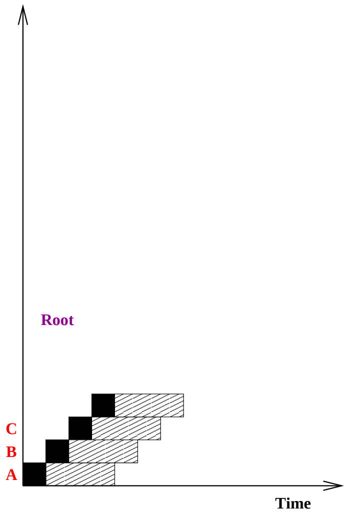

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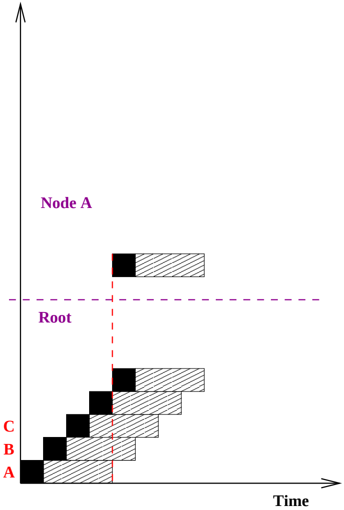

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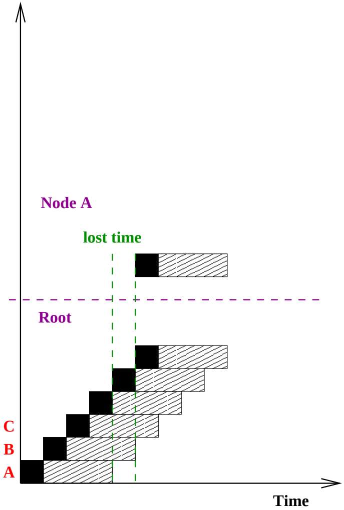

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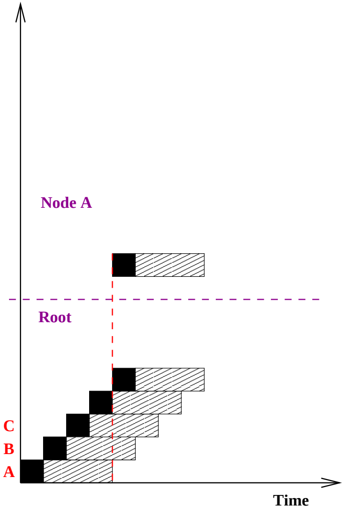

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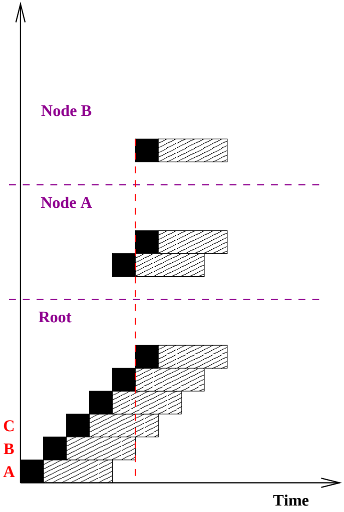

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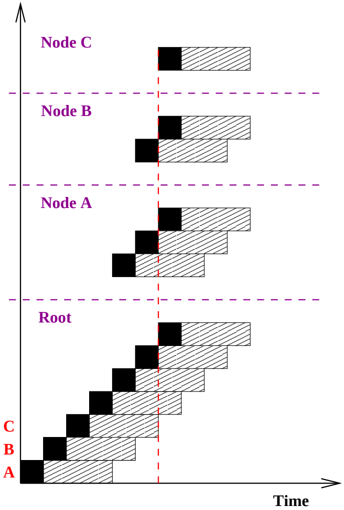

Execution time: inverse of a generalized fibonacci sequence
For 1000 nodes: $0,54s$ without overhead of the engine

Outline

1. Motivations
   - Problem
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   - Optimal
3. TakTuk
   - Engine
   - Performance
   - Perspectives

Dynamic environment

The performance of nodes and network vary

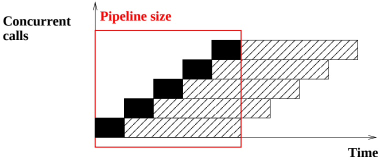
- Heterogeneous architectures in different clusters
- Load due to OS or hanged processes (zombies, infinite loop)
- External contention (network, centralized services)
- Cache effects, swap, other users, ...

The nodes cannot be considered as homogeneous
Optimal postal solution does not hold anymore

Dynamic deployment proposal

Combine dynamically local parallelization and distribution :

- Try to do things ASAP
- Nodes initiate a **batch of parallel connections**



  Ideally, this number should match the pipeline size (local parallelization window)

- Idle nodes get remaining deployment tasks by **work stealing**

Need to evaluate the pipeline size for good work balance

TakTuk engine

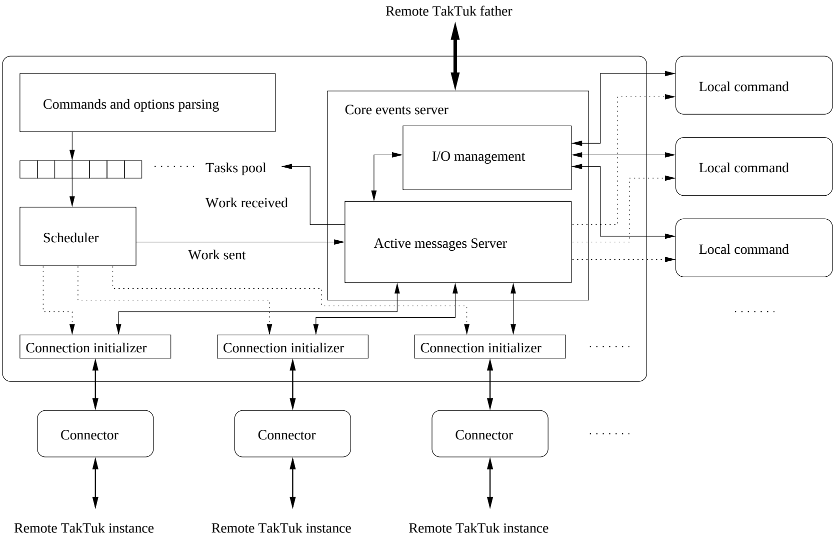
Perl implementation of the dynamic deployment proposal

- Architecture independent (tested on x86, PPC, IA-64)
- I/O and commands status multiplexing to the root
- Configurable mechanics, output templates

Suited to both administration and applications deployment

- Interactive (shell-like) mode
- Nodes logical numbering and multicast communication layer
- Distribution using adaptive work-stealing algorithm
- Insensitive to nodes failures and heterogeneity

TakTuk architecture

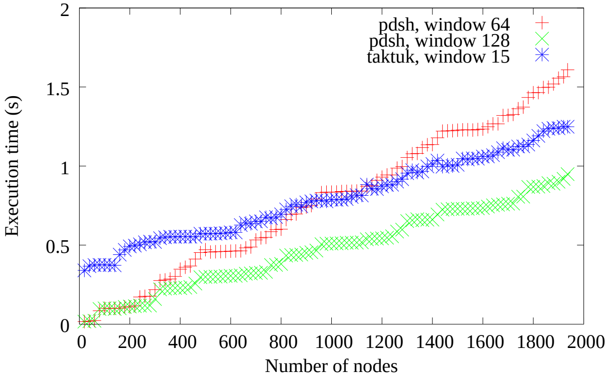


Compared to flat deployment

pdsh (clone of dsh included in IBM cluster toolsuite) :

- Local parallelization only
- Low overhead, insensitive to node failures

Using rsh (typical use in homogeneous **clusters**)



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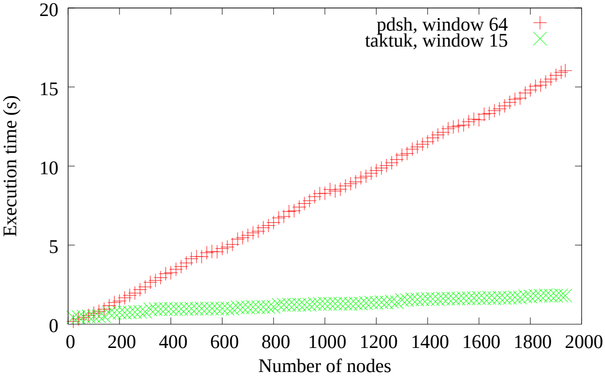


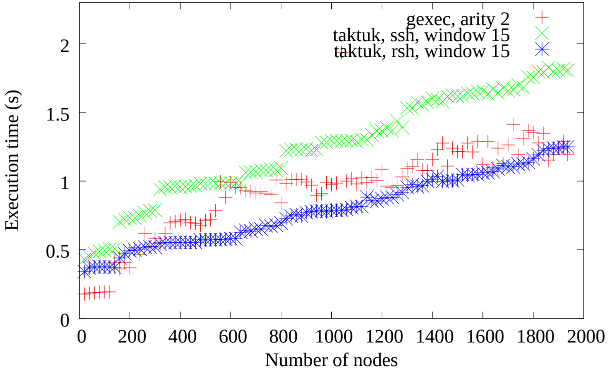
Using ssh (mandatory in **grids**)

Compared to distributed deployment

gexec (part of ganglia cluster toolsuite) :

- Distribution using n-ary tree to contact gexec daemons
- Not adaptive, cannot handle connections failure or loss

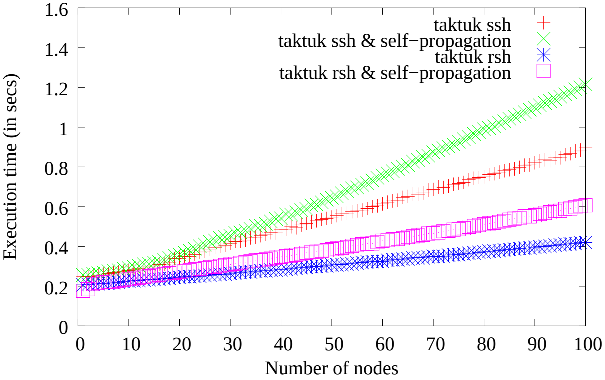
Uses ssh authentication without data encryption



No installation required with TakTuk

TakTuk can propagate itself without installation on remote node:

- Establishes connection and remotely execute a Perl interpreter
- Fetch itself through the connection



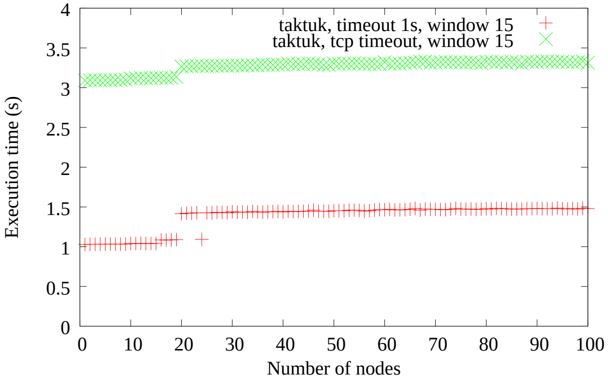
Self-propagation induces low overhead

TakTuk is insensitive to failures

Nodes unresponsiveness or connections loss do not hinder TakTuk

- Incriminated node is ignored when deploying
- ssh timeouts can be overridden for more responsiveness

gexec does not handle faults



Features comparison

	TakTuk	pdsh/dsh	gexec
Deployment capabilities			
No remote installation required	Yes	Yes	No
New connector plugin	Immediate	Simple	No
Can mix several connectors	Yes	Yes	No
Insensitive to nodes failures	Yes	Yes	No
Distributed deployment	Yes	No	Yes
Compiled engine	No	Yes	Yes
Application support			
Nodes logical numbering	Yes	No	No
Integrated communication layer	Yes	No	No
Files transfer capabilities	Yes	pdcp	PCP

Projects using TakTuk

- KAAPI : Parallel and Distributed programming environment
  - `karun` uses TakTuk to run KAAPI applications
  - KAAPI/TakTuk won ERCIM Grid@Works Plugtest for 3 consecutive years
  - Deployment of real application on 4000+ processor cores taken from 2 distinct grids
- OAR : Grid'5000 Batch Scheduler OAR uses TakTuk as a monitoring tool (test for nodes connectivity)

Conclusion and Perspectives

TakTuk

- Performs scalable parallel remote executions
- Adapts to heterogeneity
- Portable and highly configurable

Upcoming works

- Reactive and accurate adaptation of parallelization window
- Rewrite of `mpirun` using TakTuk (for some MPI distribution)
- Efficient data broadcasting using TakTuk to initiate transfers

Get TakTuk

Several ways to get TakTuk

- visit **http://taktuk.gforge.inria.fr**
- type 'TakTuk' in google
- 'apt-get install taktuk' under Debian/Ubuntu GNU/Linux

Acknowledgements

- Cyrille Martin (seminal work on TakTuk)
- Lucas Nussbaum (Debian maintainer)

Thanks for your attention

Basic usage

Identical execution on some remote nodes

```
taktuk -m toto.nowhere.com -m tata.nowhere.com
  -m tutu.nowhere.com broadcast exec [ hostname ]
```

Will output something like

```
toto.nowhere.com-1: hostname (4164): output > toto.nowhere.com
toto.nowhere.com-1: hostname (4164): status > 0
tutu.nowhere.com-3: hostname (1468): output > tutu.nowhere.com
tutu.nowhere.com-3: hostname (1468): status > 0
tata.nowhere.com-2: hostname (3290): output > tata.nowhere.com
tata.nowhere.com-2: hostname (3290): status > 0
```

Basic usage

Do not necessarily require an installed TakTuk on each remote host

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Effect of the `-s` switch

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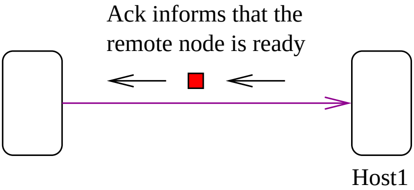

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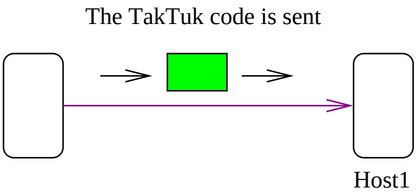

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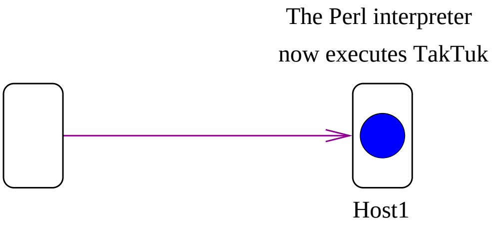

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```
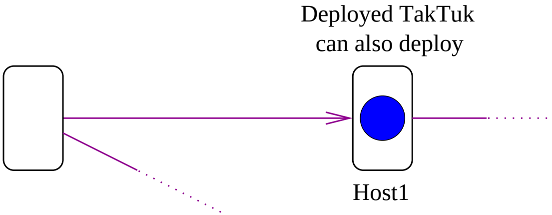

Effect of the `-s` switch



Basic usage

Commands can also be given:

- interactively
- on a per host basis

```
taktuk -m toto.nowhere.com -[ exec [ hostname ] -]
  -m tata.nowhere.com -[ exec [ uptime ] -]
  -m tutu.nowhere.com -[ exec
    [ if [ \$RANDOM -gt 1000 ];then echo ok;fi ] -]
```

And the set of remote nodes can be listed in a file

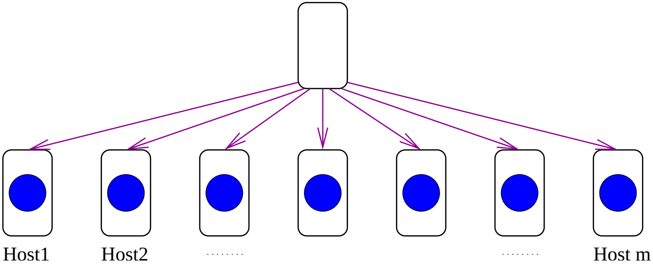
```
taktuk -f $OAR_NODE_FILE broadcast exec [ hostname ]
```

Flat tree topology

Deployment tree is constructed dynamically by work-stealing

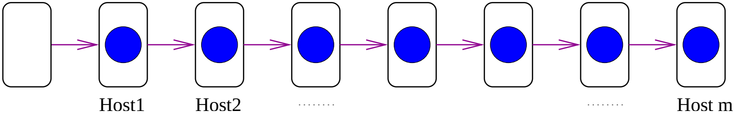
- it can be changed using TakTuk options
- by disabling work-stealing we get a flat tree

```
taktuk -d-1 -m host1 -m host2 ... -m hostm
  broadcast exec [ hostname ]
```



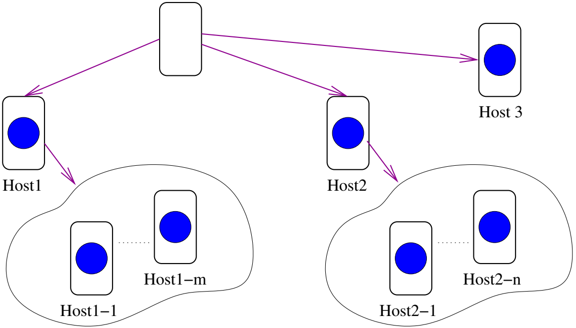
Chain topology

```
taktuk -m host1 -[
         -m host2 -[
           ... -[ -m hostm -] ...
         -]
       -]
  broadcast exec [ hostname ]
```



Mixed static/dynamic topology

```
taktuk -m host1 -[ -m host1-1 ... -m host1-m -]
       -m host2 -[ -m host2-1 ... -m host2-n -]
       -m host3 broadcast exec [ hostname ]
```



Communication layer

Locical numbering given using environment variables

- TAKTUK_RANK
- TAKTUK_COUNT

Communication between logical entities

- provided by taktuk Perl package or taktuk_perl command
- send/receive model
- multicast send
- receive can be timeouted

Communication example

- communicating script: communication.pl

```
if ($ENV{TAKTUK_RANK} == 1) {
    if ($ENV{TAKTUK_COUNT} > 1) {
        taktuk::send(to=>2, body=>"Salut a toi");
      }
  }
elsif ($ENV{'TAKTUK_RANK'} == 2) {
    my ($to, $from, $message) = taktuk::recv();
    print "Received $message from $from\n";
  }
```

- TakTuk command

```
taktuk -m host1 -m host2 broadcast taktuk_perl [ ],
  broadcast input file [ communication.pl ]
```