Making Cloud Easy:
Design Considerations and First Components of a Distributed Operating System for Cloud

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3rd generation cloud design principles

- Datacenter is abstracted as Single System
- All cloud services are fully distributed
- Datacenter capacity organically adapts and self-configures
- All resources belong to a single resource manager
- Different communication mechanisms for different “distances”
- Set of communication abstractions structured along a latency gradient

Differences from previous SSI work

- No distributed kernel
  - Single server Linux kernel used as a modular system component
    - Provides virtual memory and thread management
  - Other operating system services like process creation and resource management are distributed
- No distributed shared virtual memory or distributed thread management
  - Processes get only as much virtual memory as on a single machine and only as many threads as the local Linux OS can provide
- Monolithic applications are not distributed automatically as SSI suggests
  - Applications need to be designed modularly for distribution

Our work: SSI for Cloud Native

Image source from top to bottom:
https://www.zerostack.com/cloud-native-apps-icons-hover/
http://www.iet.unipi.it/a.bechini/concur/concur.html

Addressing pain points in existing cloud platforms

- OpenStack
  - Remove lower bound on minimum unit of deployment without impacting scale up potential
    - Processes rather than VM images for execution context
  - Remove need for programmer to deal with virtual networks and infrastructure programming
  - Reduce the administration effort, simplify upgrade and maintenance
- Kubernetes
  - Add native tenant management to improve potential for resource and capacity sharing
  - Replace networking with IPC to simplify service interface and improve performance
- Overall
  - Reduce the number of execution context layers
  - Improve co-ordination between layers

Making 3rd generation cloud real

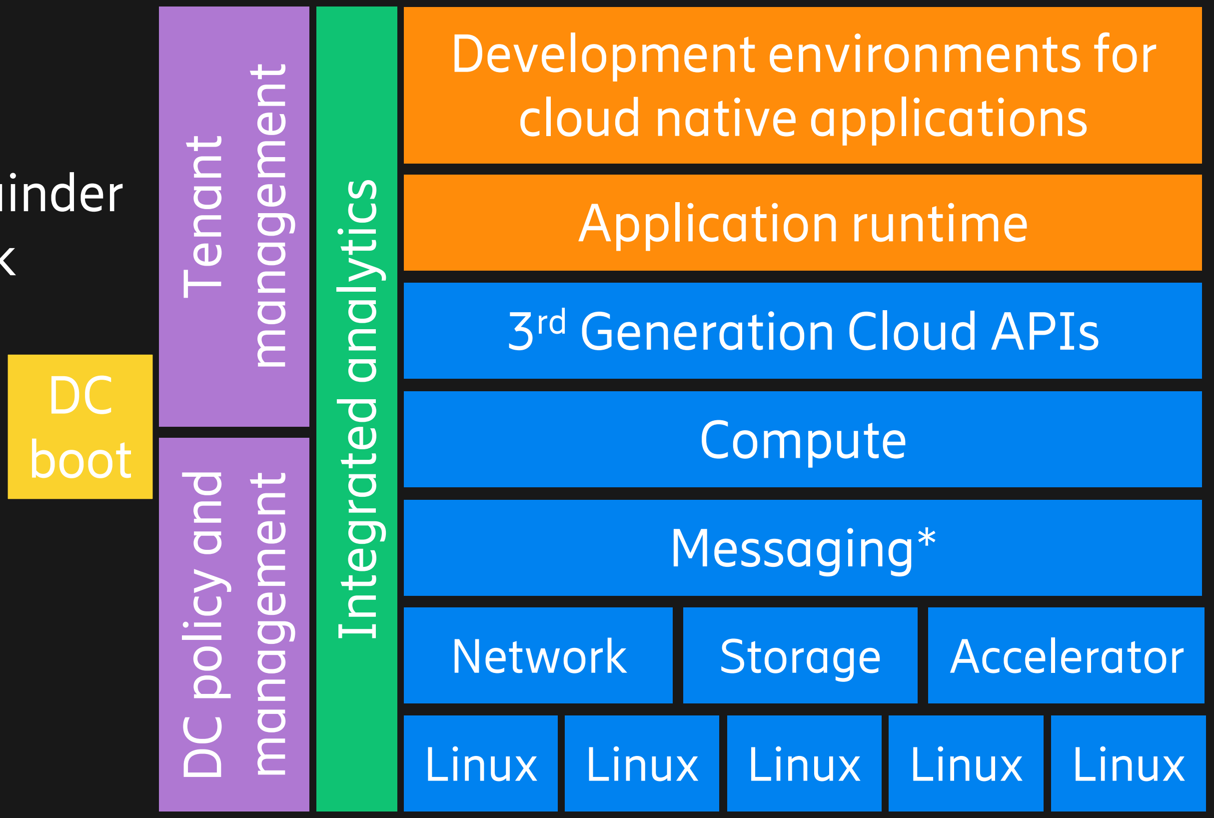
Implemented now:

- Single System Image
  for easy development and deployment of applications
- Automatic resource federation
  for easy setup of datacenter resources
- Message bus for structured, fast control plane messaging
- Blockchain
  based tenant management
  with smart contracts

Remainder of talk

Under development:

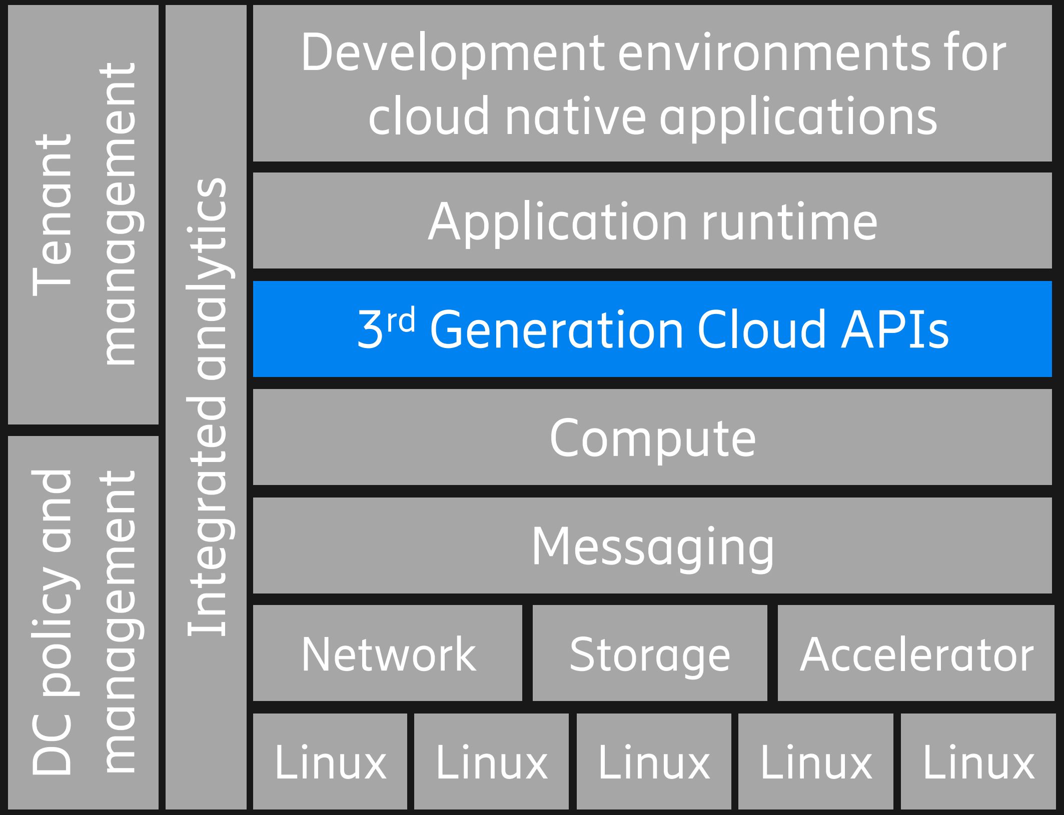
- Serverless application runtime
  with fast key-value store for state handling
- Single touch installation, configuration and upgrade
- Acceleration through domain specific hardware



* Together with RISE and VINNOVA

Nefele SDK

- The SSI abstraction is fronted to the developer through an SDK library
  - Structured like the Linux *libc* OS Syscall library
- SDK library is *libnefele*
  - C library for now (Python and Golang under test)
  - All API calls block until the call completes
- Currently implemented functions
  - Process management (creation, deletion, etc.)
- Legacy
  - Filesystem uses legacy Linux API
  - Linux *libc* calls are also available for single machine operations



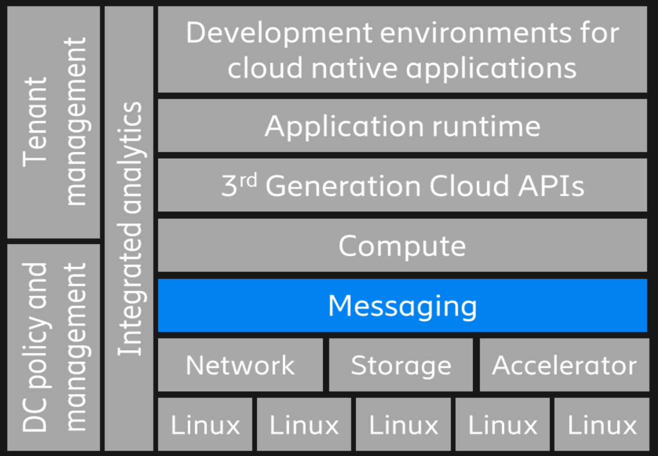
Hermoðr Stack

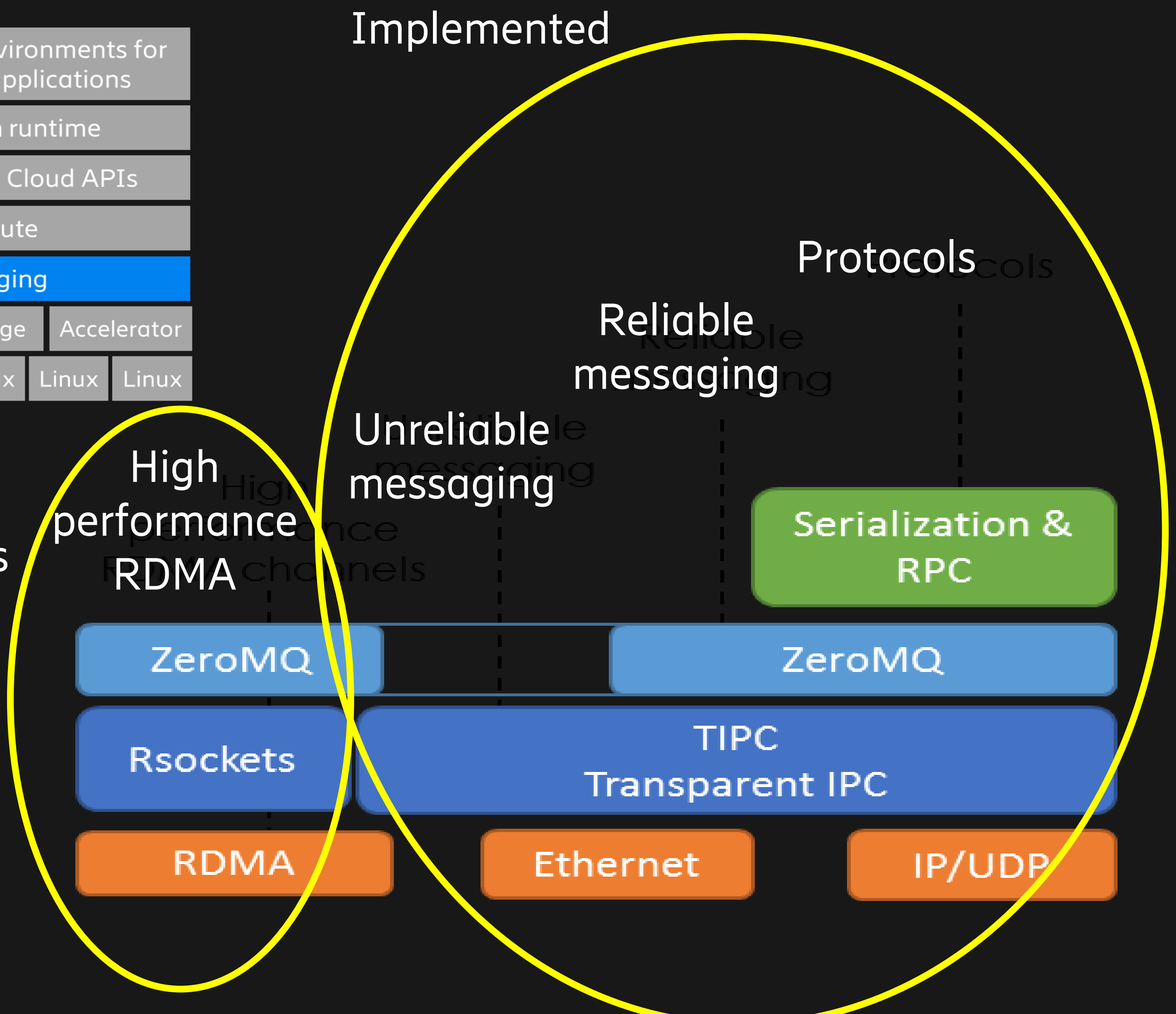
Processes commuicate through mailboxes

Messages in Google protobuf format

Three addressing schemes:

- Random addresses similar to TIPC ports
- Assigned and distributed location-independent numbered services from TPIC
- Symbolic string based names





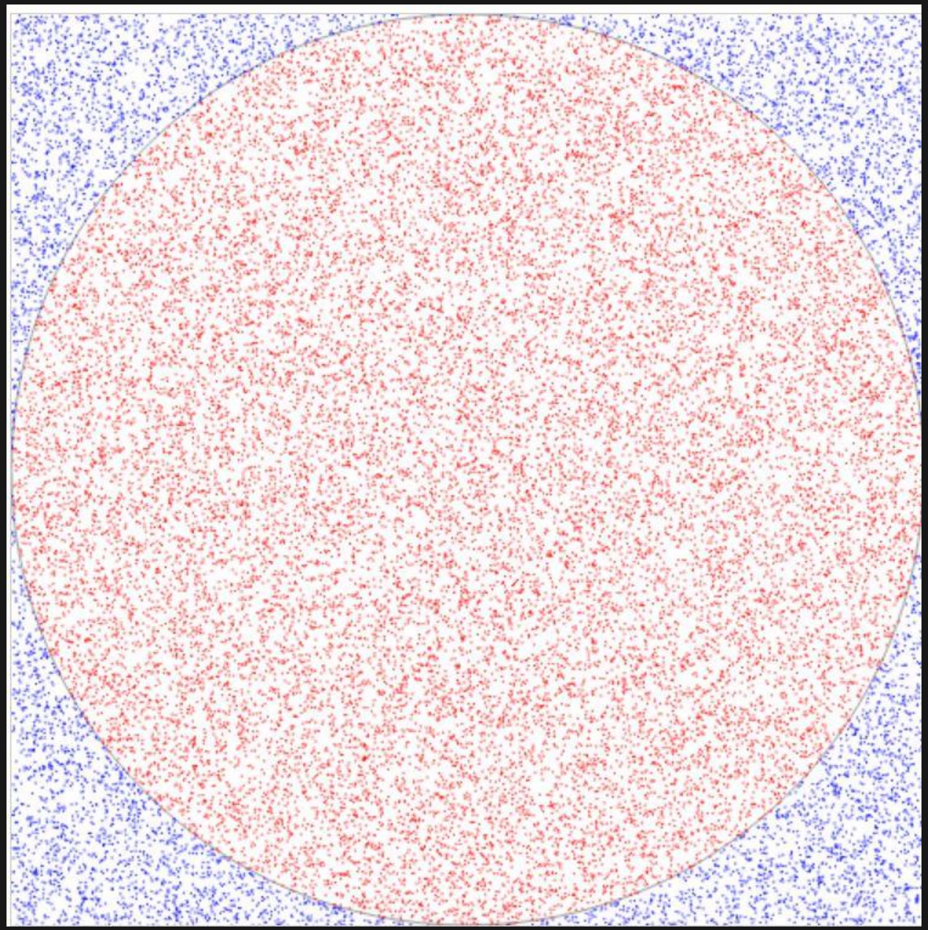
Estimating π using Monte Carlo simulation

— Generate points uniformly distributed at random over a 1x1 square.

— Keep track of points inside a circle with radius 0.5 and points outside
  — Blue is outside, red is inside
  — Area of circle is $\pi r^2 = \pi / 4$

— Divide N_{inner} by N_{total} should give an estimate of $\pi/4$

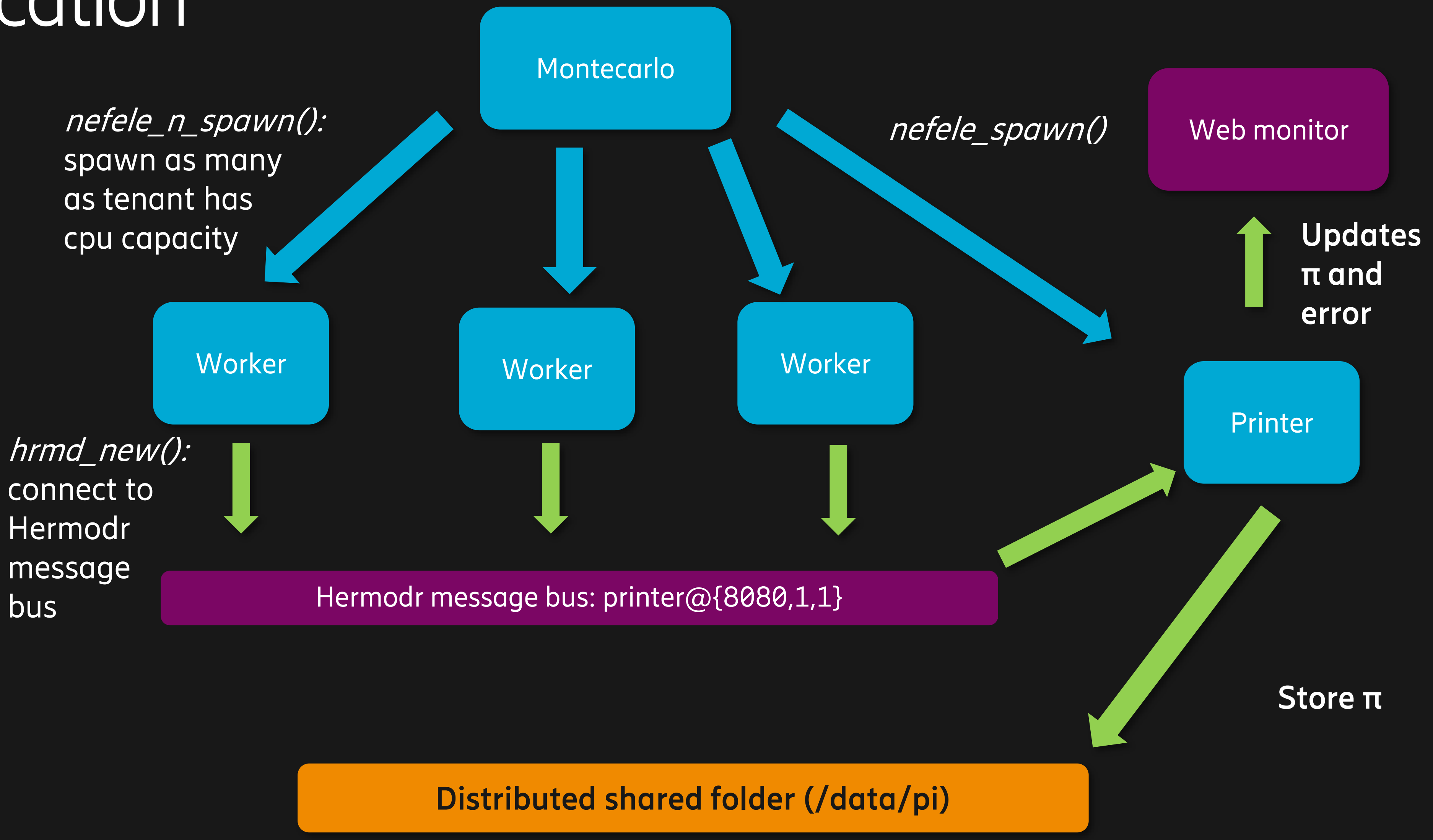
— Multiply by 4 for π



Sample application

MonteCarlo simulation to estimate π.

Parallell simulations to rapidly increase precision.



Monte Carlo main program

```
int main(int argc, char* argv[]) {
   (…)
   char* worker = "/usr/bin/montecarlo_worker";
   char* printer = "/usr/bin/montecarlo_printer";

   nefele_spawn(&pid_printer, printer, p_arg, …);
   (…)

   do {
      (…)
      nefele_n_spawn(pids, new_req, worker, w_arg, …);
      nefele_waitpid(0, &status, 0);
   } while (pending > 0 || completed < N1);

   nefele_kill(pid_printer, 9);
   printf(…);
}
```

Control Plane

Monte Carlo worker program

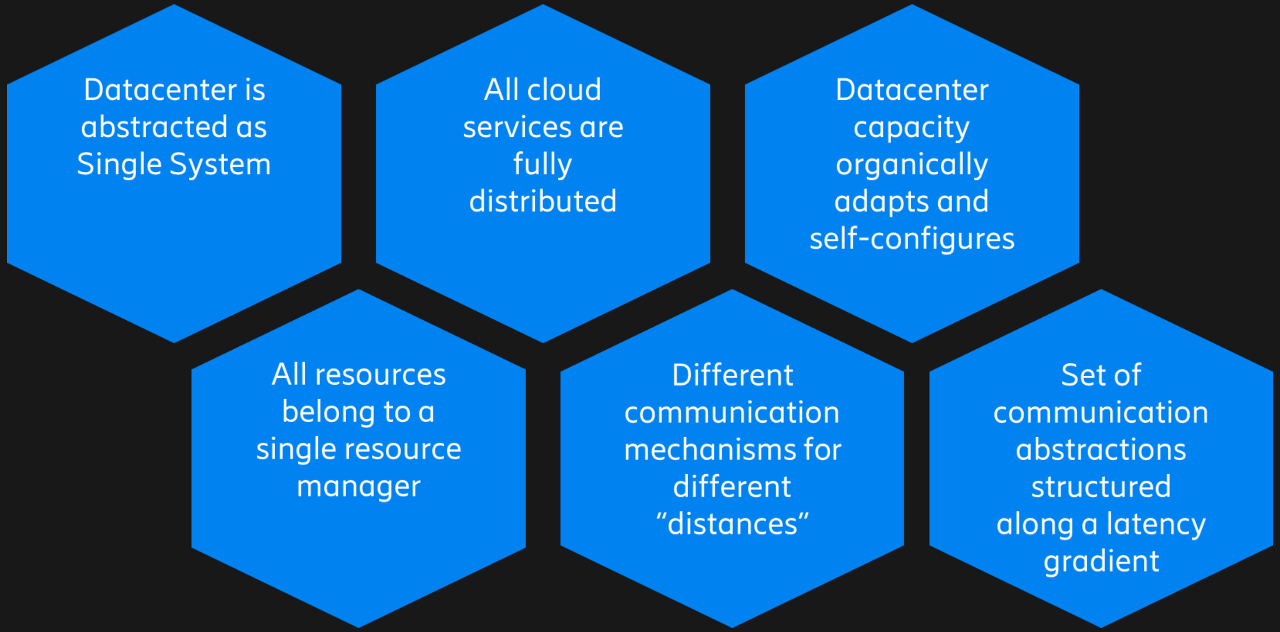
```
int main(int argc, char* argv[]) {
   (…)
   msg.t = monte_carlo_count_pi(N2);
   msg.n = N2;
   (…)

   if (hrmd_service_exists(hrmd,
                           "printer@{8080,1,1}",
                           10000)) {
        hrmd_message(hrmd,
                     "printer@{8080,1,1}",
                     (const byte*) &msg,
                     sizeof(msg));
   }
    (…)
}
```

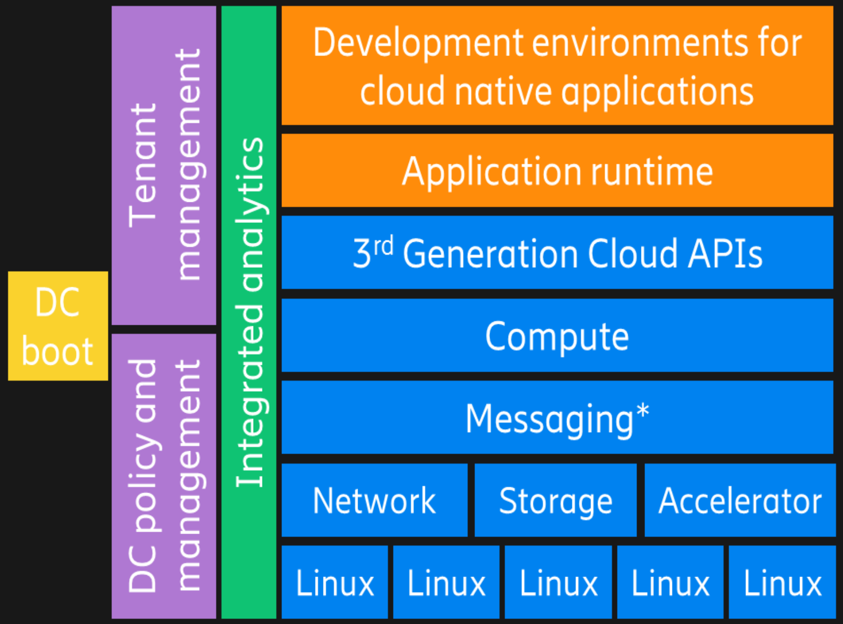
Parallel task
worker

Assumptions, Open Issues, and Feedback

- Assumptions
  - Designing cloud management software as a *system* to remove the need for infrastructure programming and simplify networking will:
    - Radically reduce the amount of work a developer needs to go through to develop and deploy applications into a cloud
    - Radically reduce the amount of work needed to manage cloud infrastructure
      - Partially this will be due to being able to design management automation in from the start rather than having to patch it in later
- Open Issues
  - Will the Single System approach work without distributed shared virtual memory and distributed thread management?
  - Can our approach better support Kubernetes and other Cloud Native Foundation technologies and serverless programming than running on Openstack or directly on Linux?
  - Can our approach better support emerging application classes like the RiseLab Ray AI application framework?
- Feedback
  - IPC v.s. IP for communication and exposing latency to the developer?
  - How to incorporate policy?
  - Management of storage?

Single System Image for Cloud Native: Key Ideas





- Use processes instead of VMs for execution context
- Use IPC instead of IP for communication locally, expose latency to the developer to allow them to compensate in their designs
- Design cloud systems management to be automated rather than automate it after designed