Developing and Deploying Microservices with Toro Kernel

www.torokernel.io

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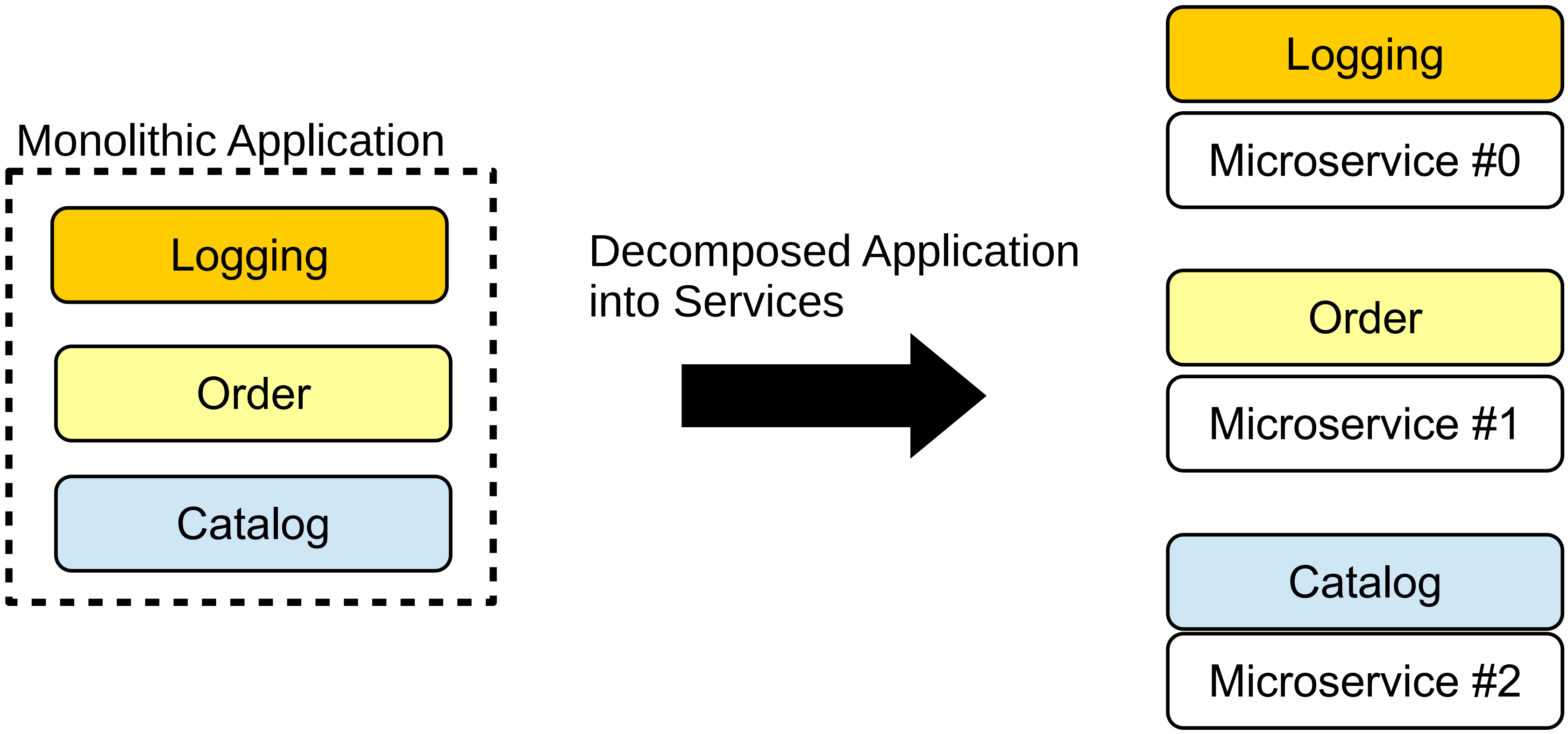
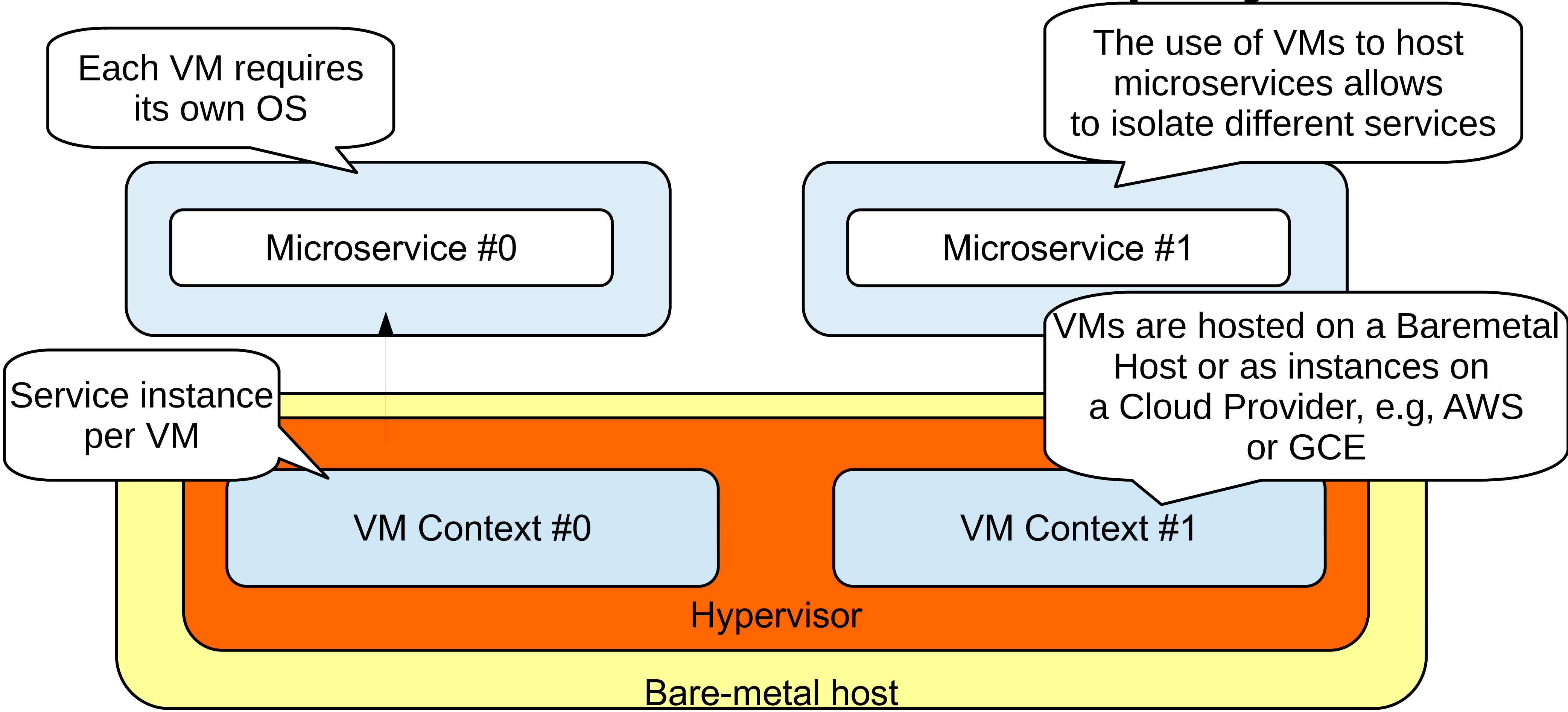
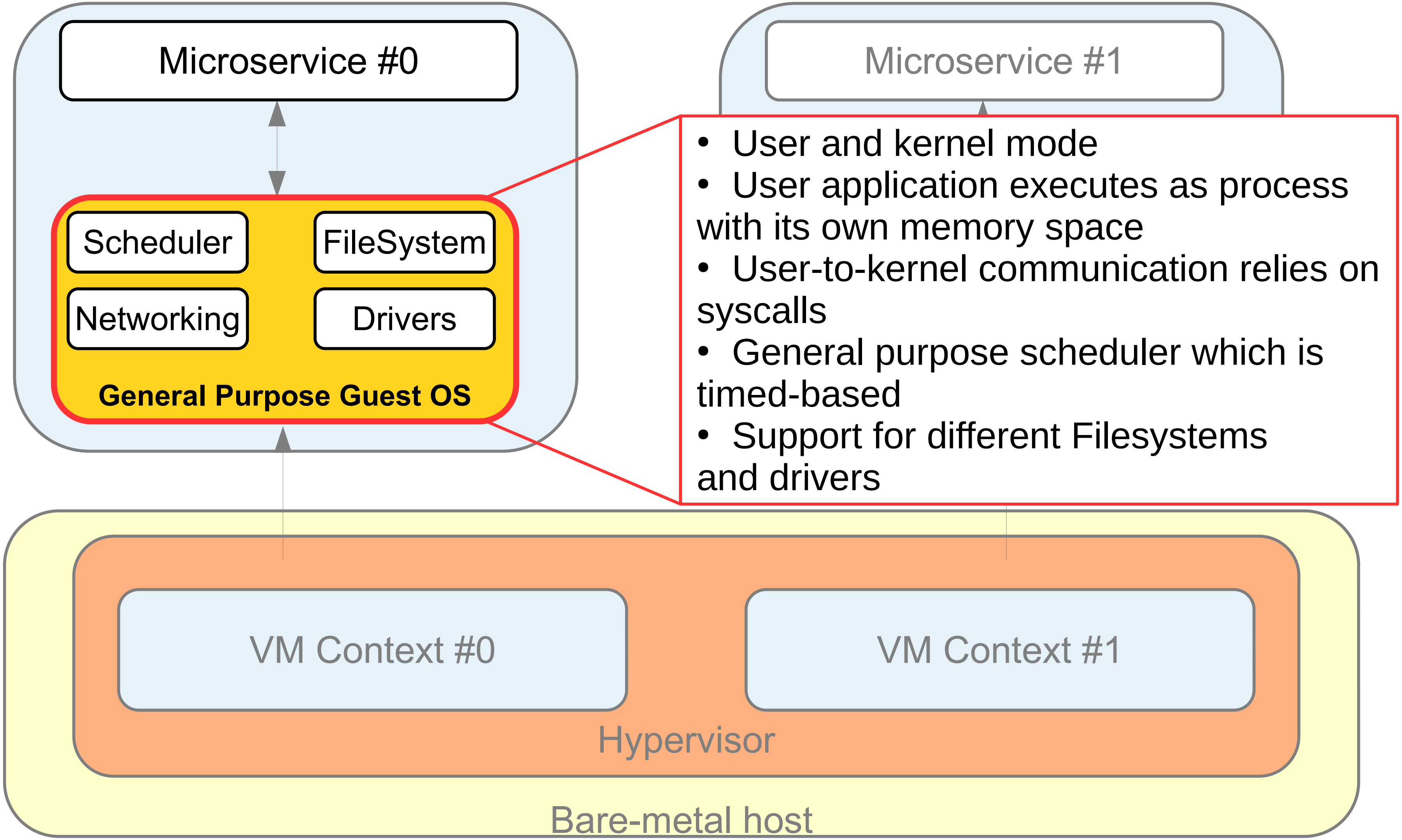
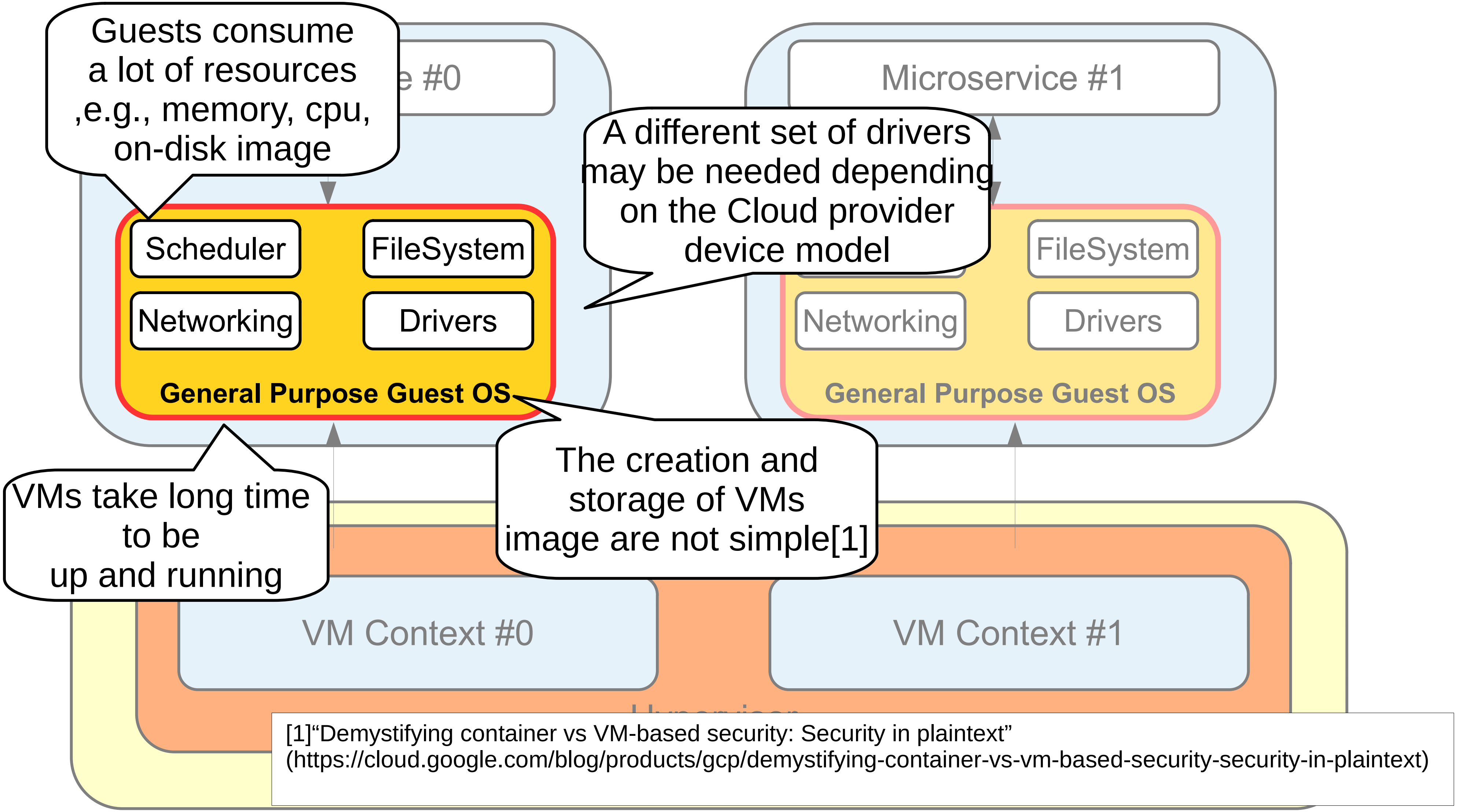
What are microservices?



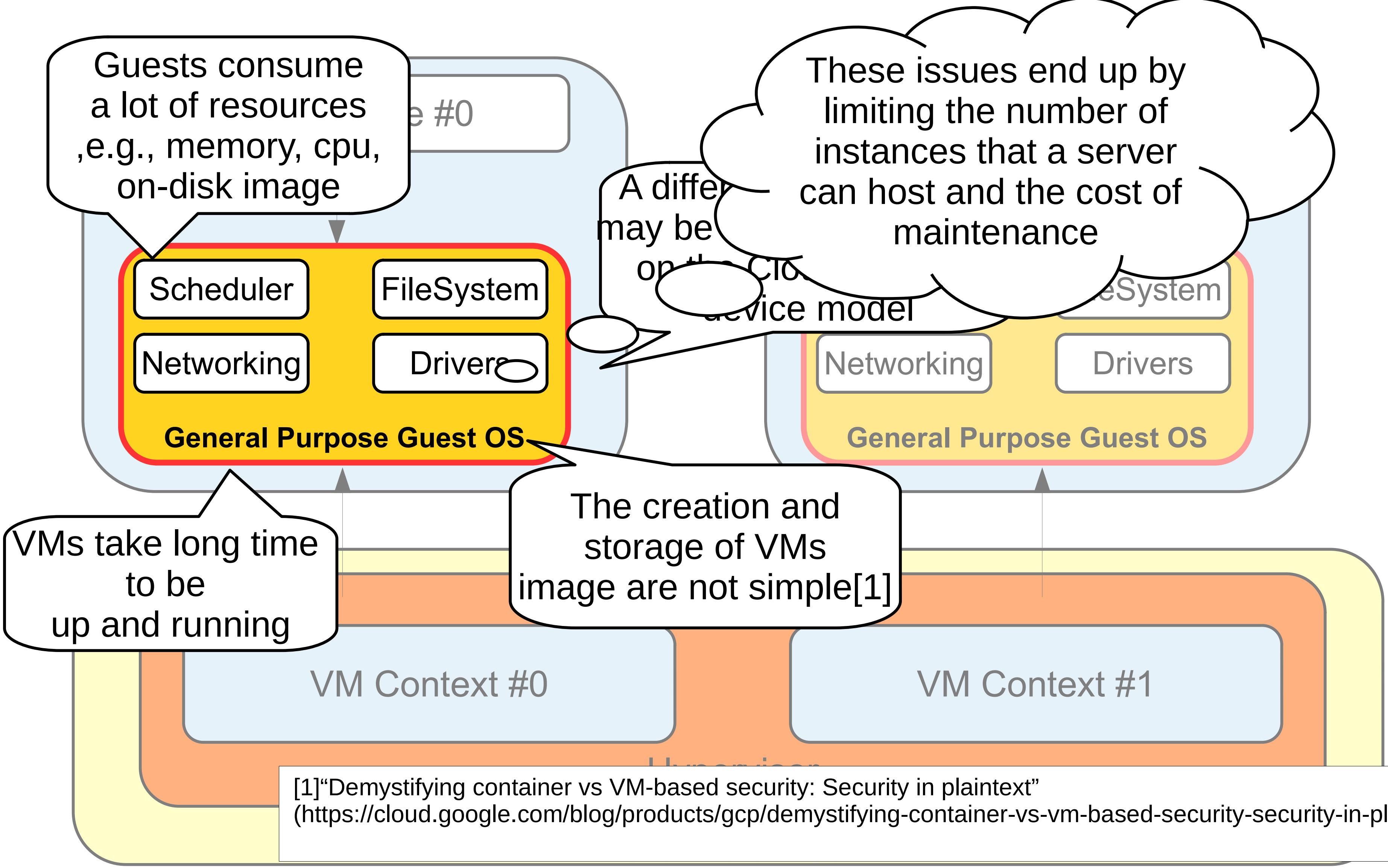
How are microservices deployed?




Microservice #0
Scheduler
FileSystem
Networking
Drivers
General Purpose Guest OS
Microservice #1
• User and kernel mode
• User application executes as process with its own memory space
• User-to-kernel communication relies on syscalls
• General purpose scheduler which is timed-based
• Support for different Filesystems and drivers
VM Context #0
VM Context #1
Hypervisor
Bare-metal host



[1]"Demystifying container vs VM-based security: Security in plaintext" (https://cloud.google.com/blog/products/gcp/demystifying-container-vs-vm-based-security-security-in-plaintext)



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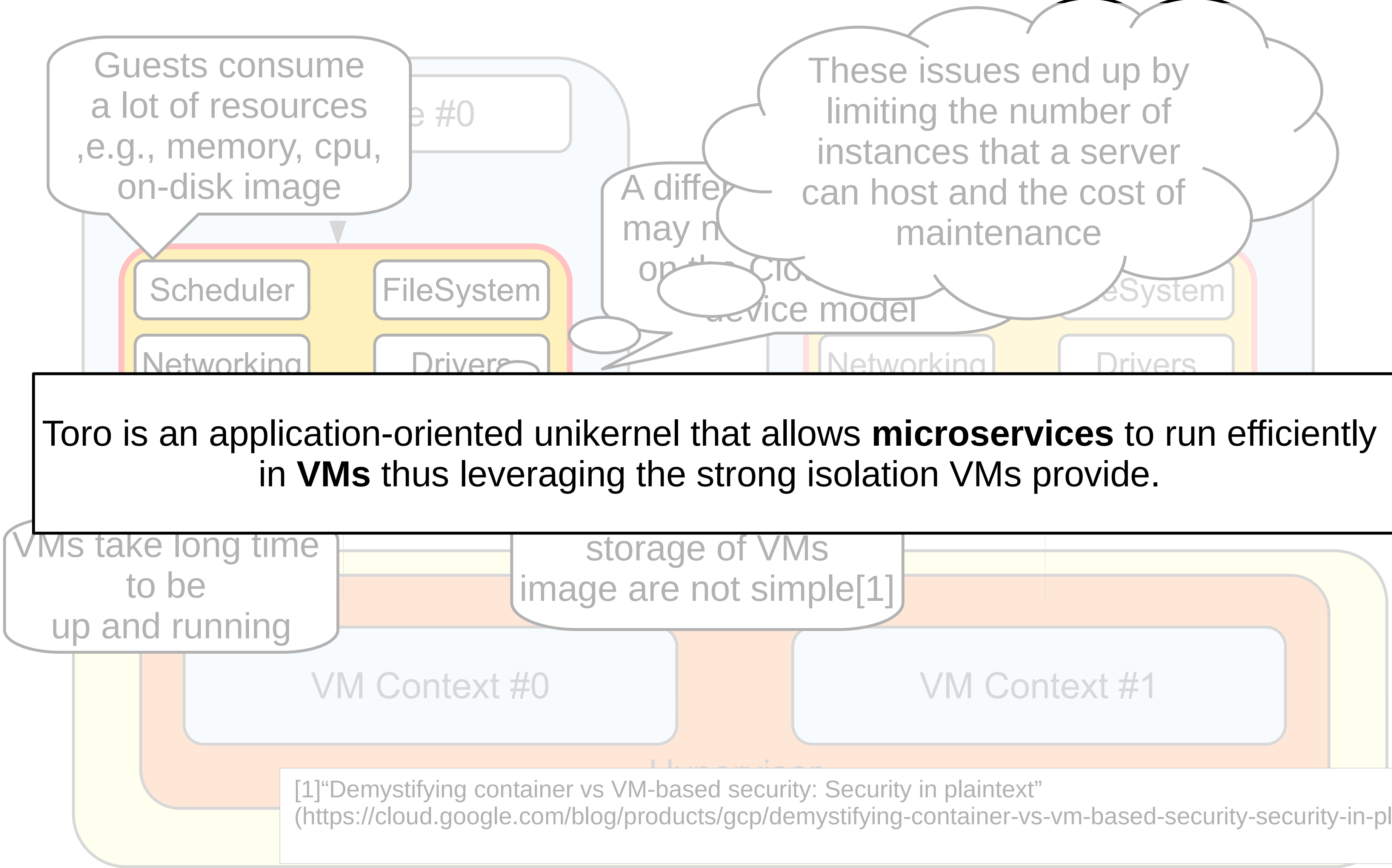

Toro is an application-oriented unikernel that allows **microservices** to run efficiently in **VMs** thus leveraging the strong isolation VMs provide.

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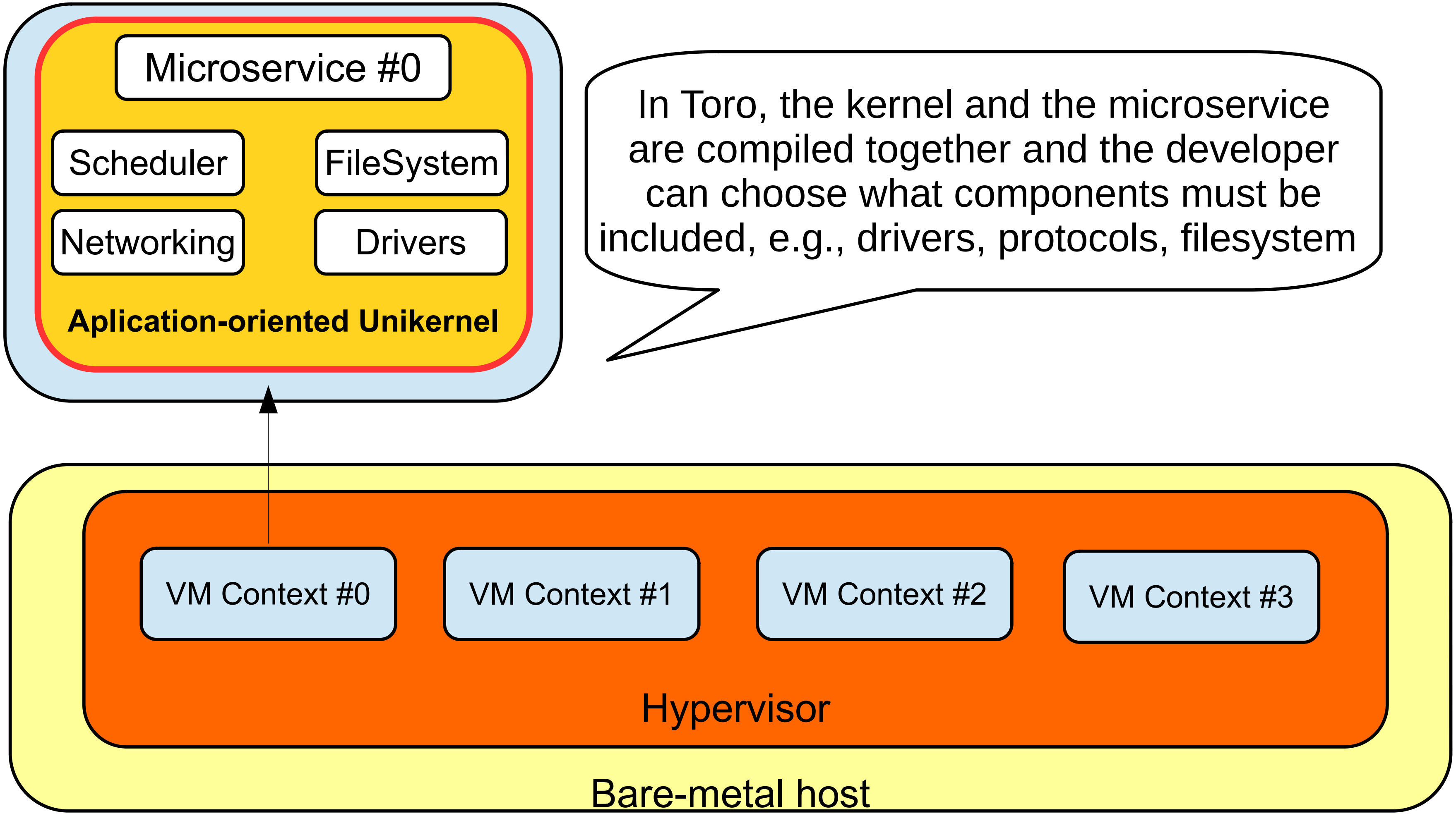
Microservice #0
Scheduler
FileSystem
Networking
Drivers
Aplication-oriented Unikernel
In Toro, the kernel and the microservice are compiled together and the developer can choose what components must be included, e.g., drivers, protocols, filesystem
VM Context #0
VM Context #1
VM Context #2
VM Context #3
Hypervisor
Bare-metal host

Ingredients for ToroKernel

- A kernel’s architecture that improves the execution of a single user application which is based on:
  - Simple Scheduler
  - Dedicated Resources
- A kernel’s architecture that improves the execution of a single user application as a guest by providing:
  - Fast instantiation of user application
  - Reduced guest’s footprint
  - Improved netwoking and filesystem by relying on VirtIO devices

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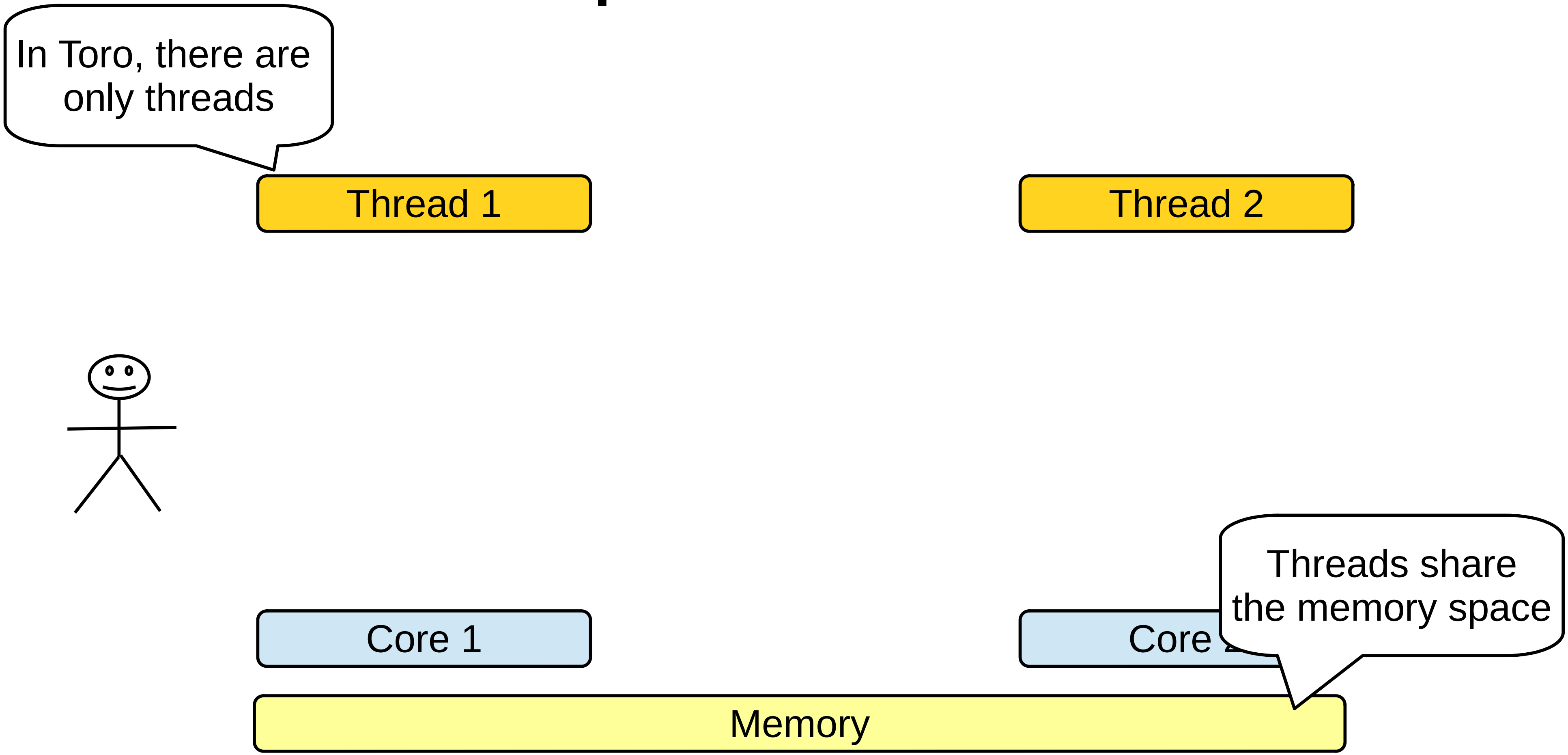
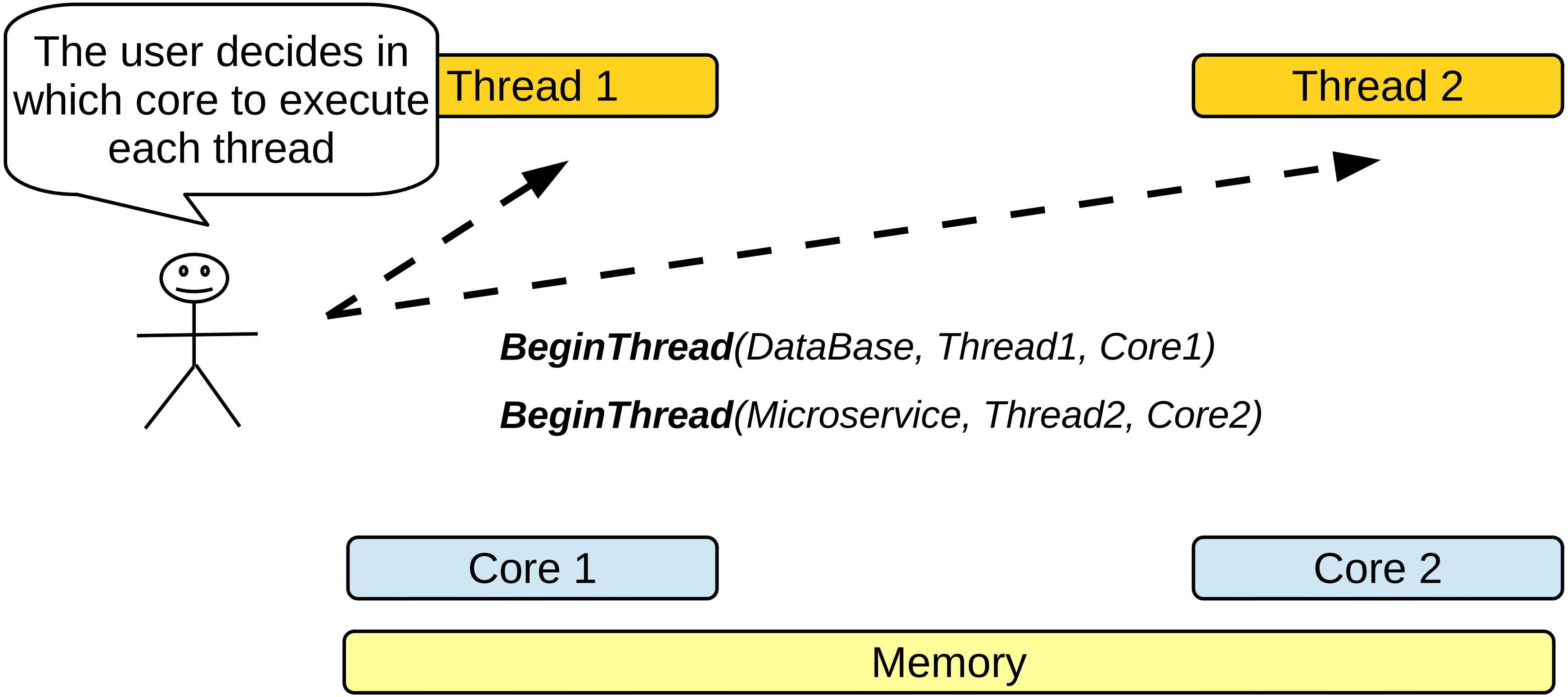
Simple Scheduler Requirements

- Scale with the number of cores
- Simple scheduler’s algorithm, i.e., Cooperative threading model
- Minimalist context switches

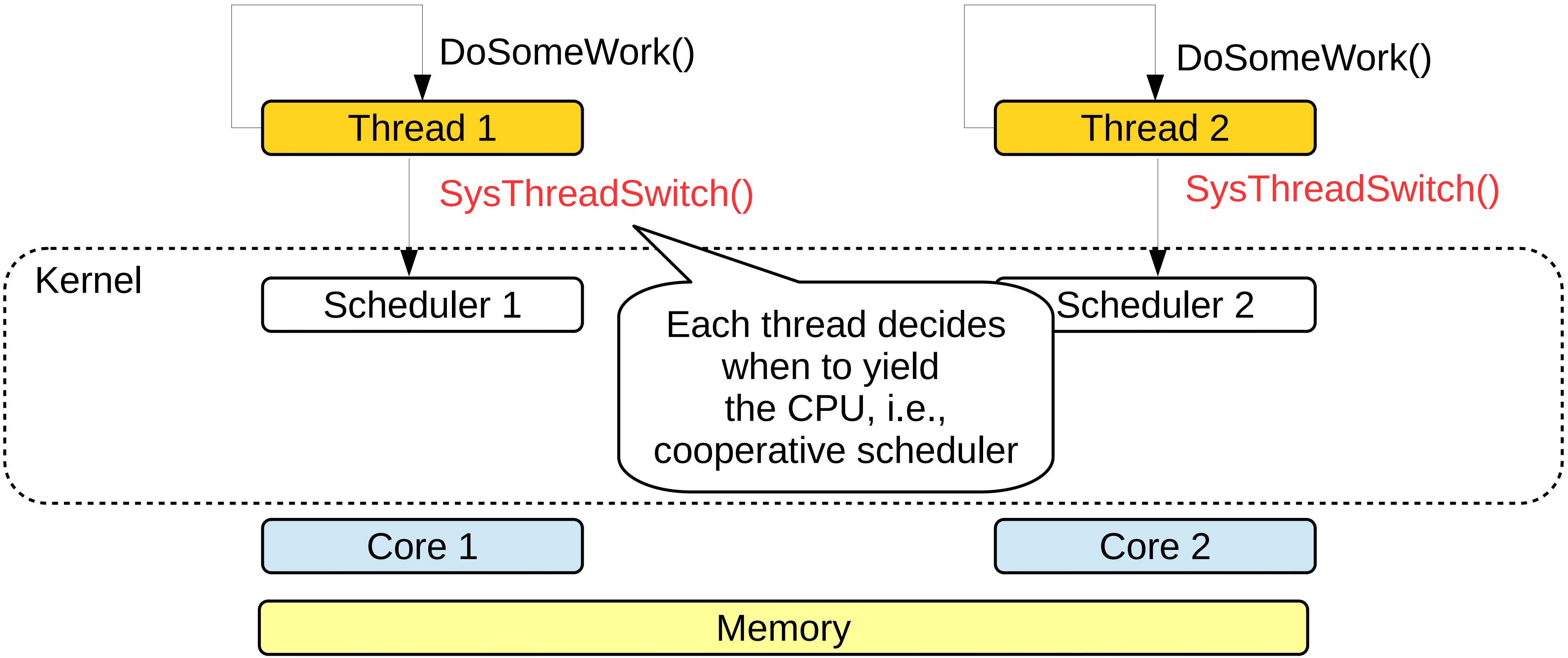
Simple Scheduler



Simple Scheduler



Simple Scheduler



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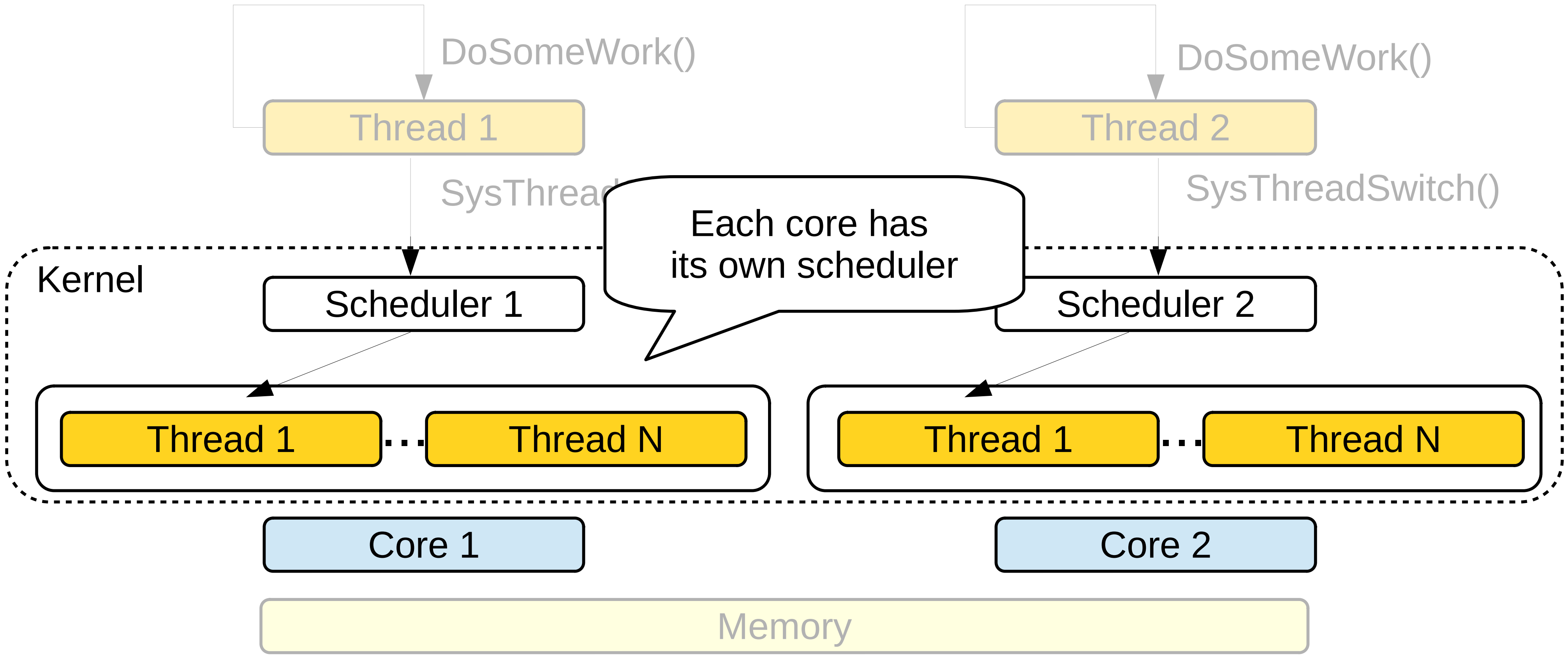
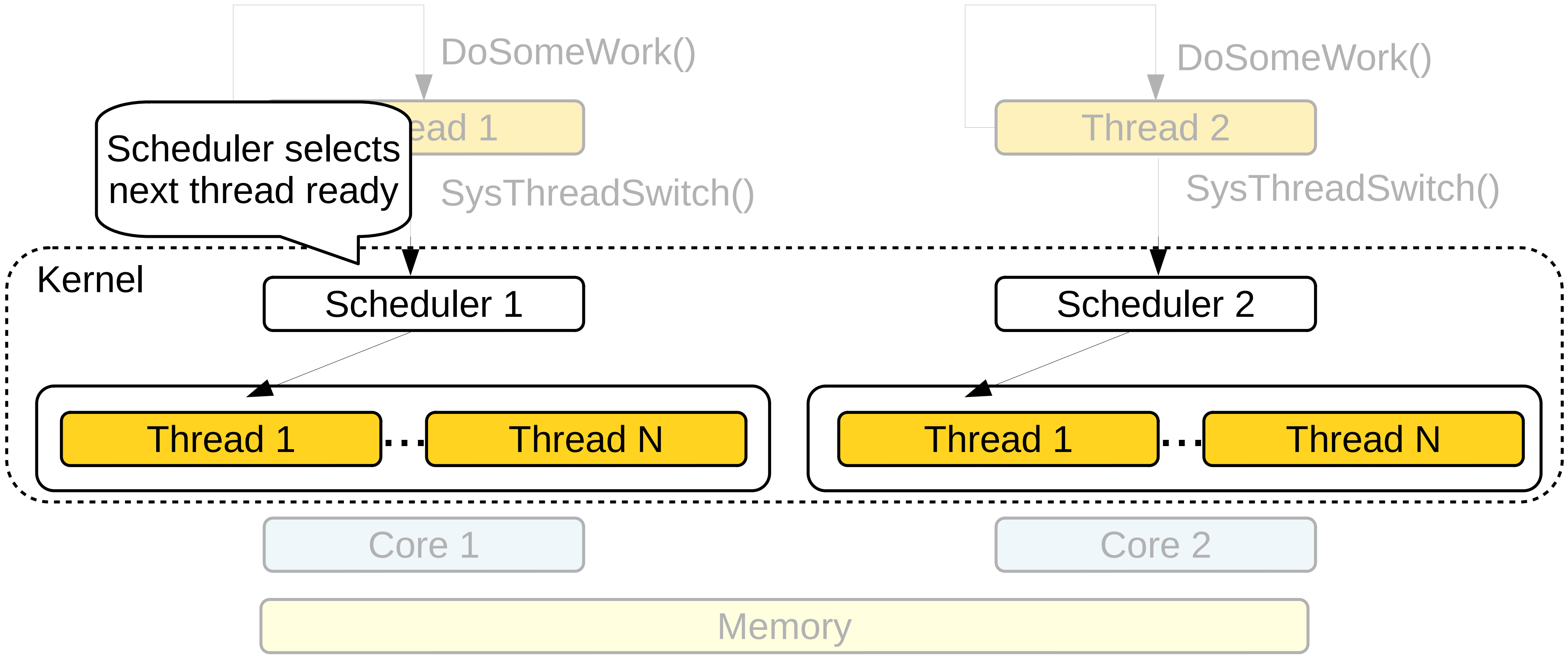
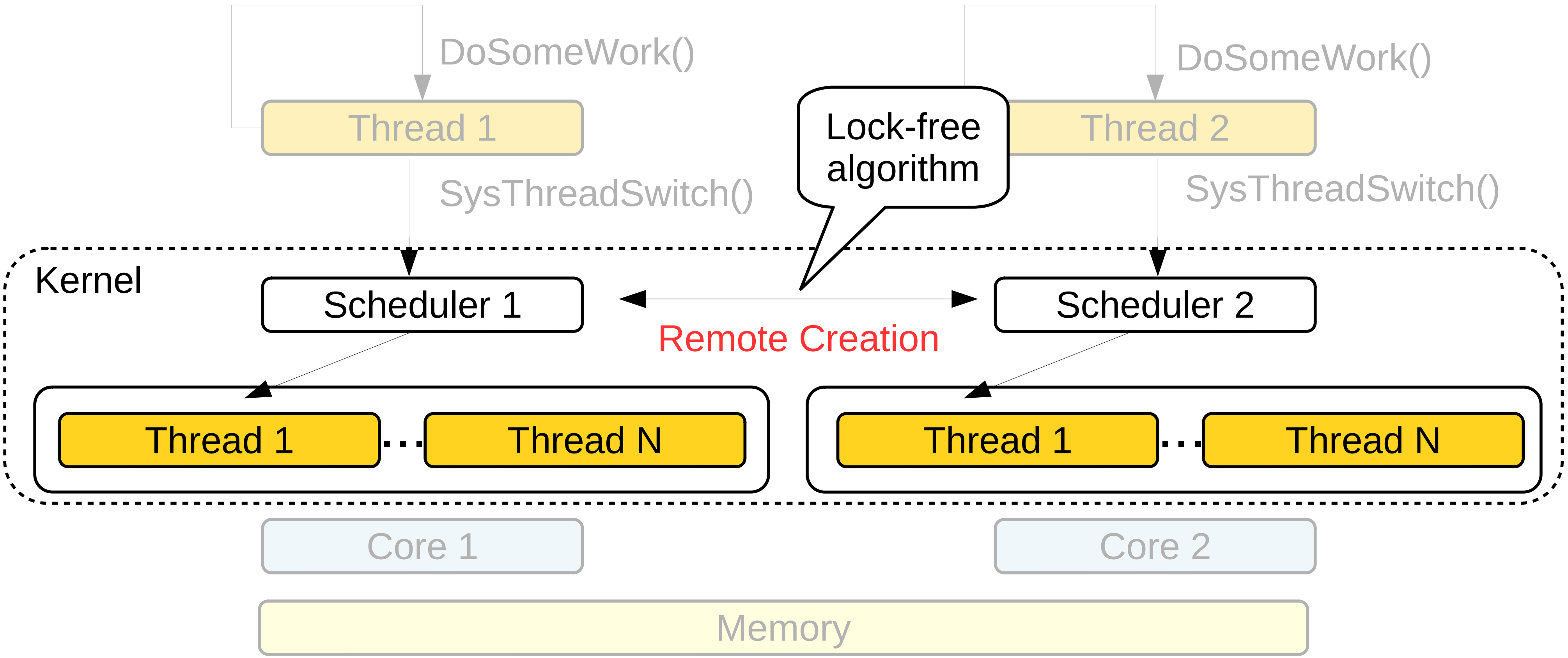


Simple Scheduler



Simple Scheduler



Benefits of Simple Scheduler

- The use of threads makes context switching cheaper
- The use of a cooperative scheduler:
  - simplifies user’s and kernel’s code by avoiding to implement protection inside the scheduler
  - reduces number of context switches since it does not relies on interruptions

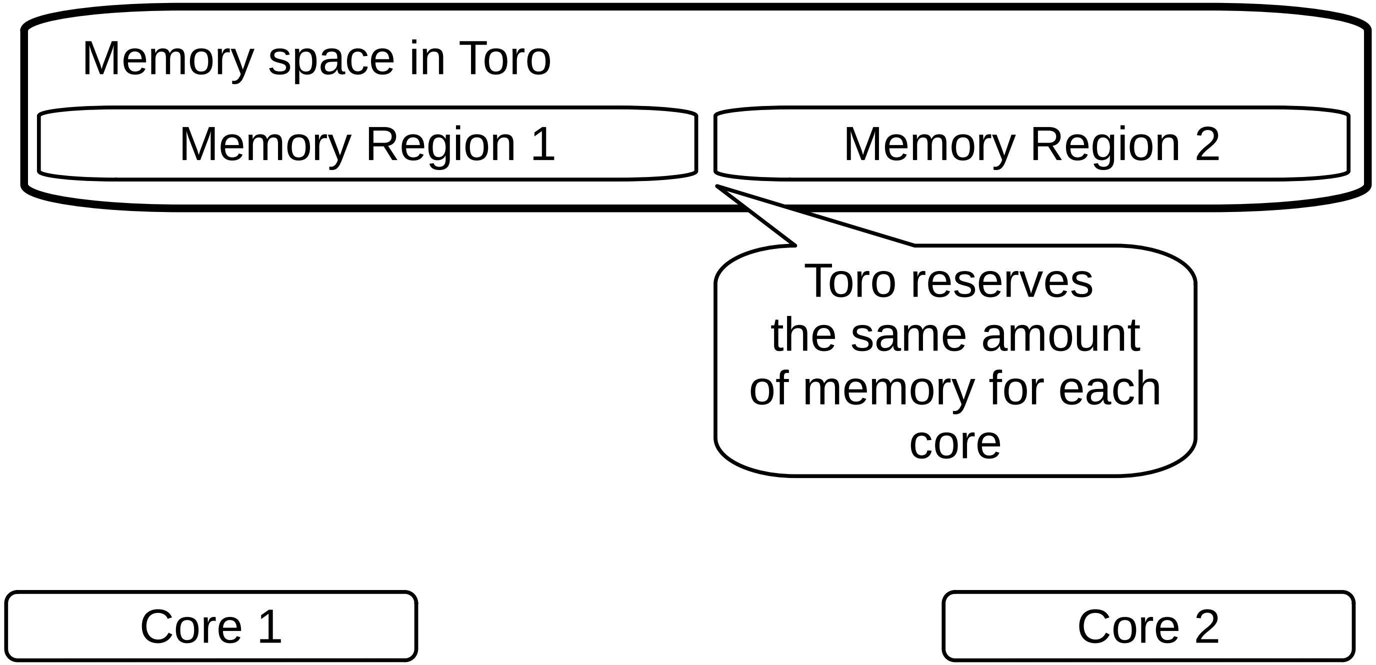
Dedicated Resources

- In a multicore system, the problematic resource is the shared memory. The use of shared memory causes:
  - Overhead in the memory bus
  - Overhead in the cache to keep it coherent
  - Overhead to guaranty mutual exclusion when spin-locks are used

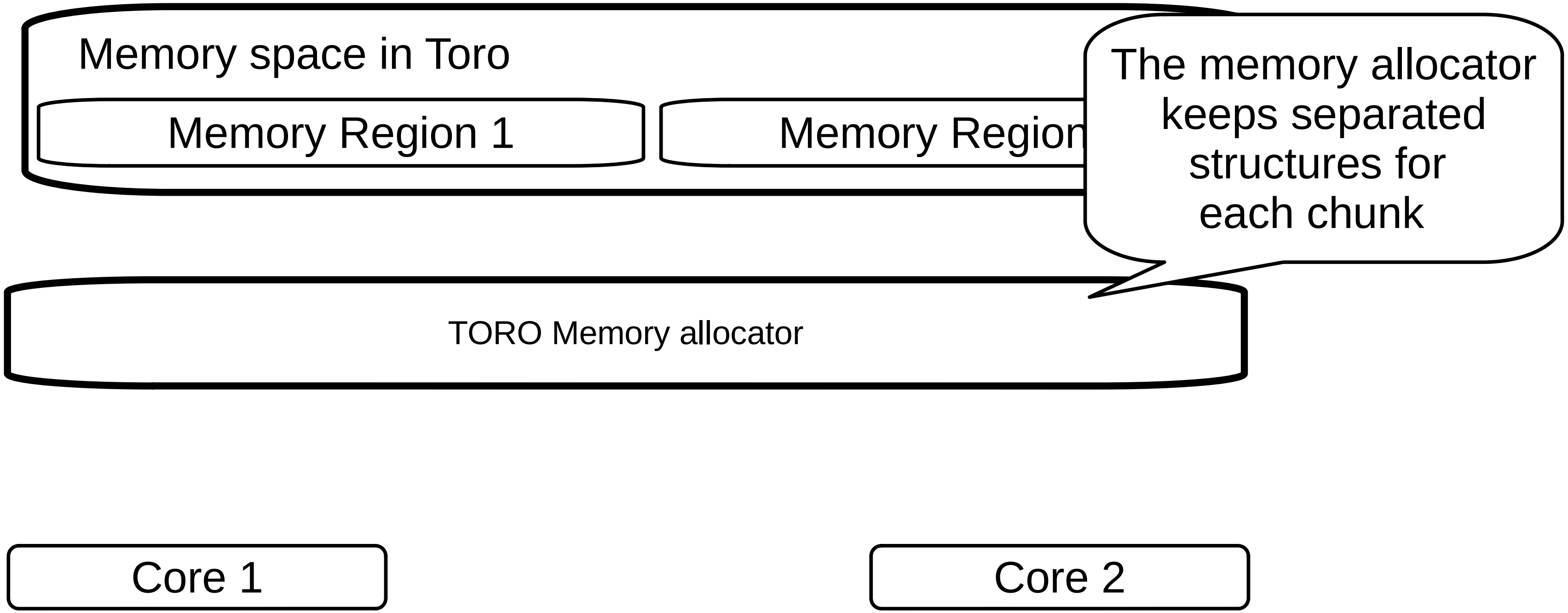
Dedicated Resources Proposal

- Toro improves memory access by
  - keeping the resources locals:
    - The memory is dedicated per core
    - The kernel data structures are dedicated per core
    - The access to kernel data structures is lock free
  - leveraging NUMA technologies, e.g., Hypertransport, Intel QuickPath

Dedicated Resources Memory



Dedicated Resources
Memory



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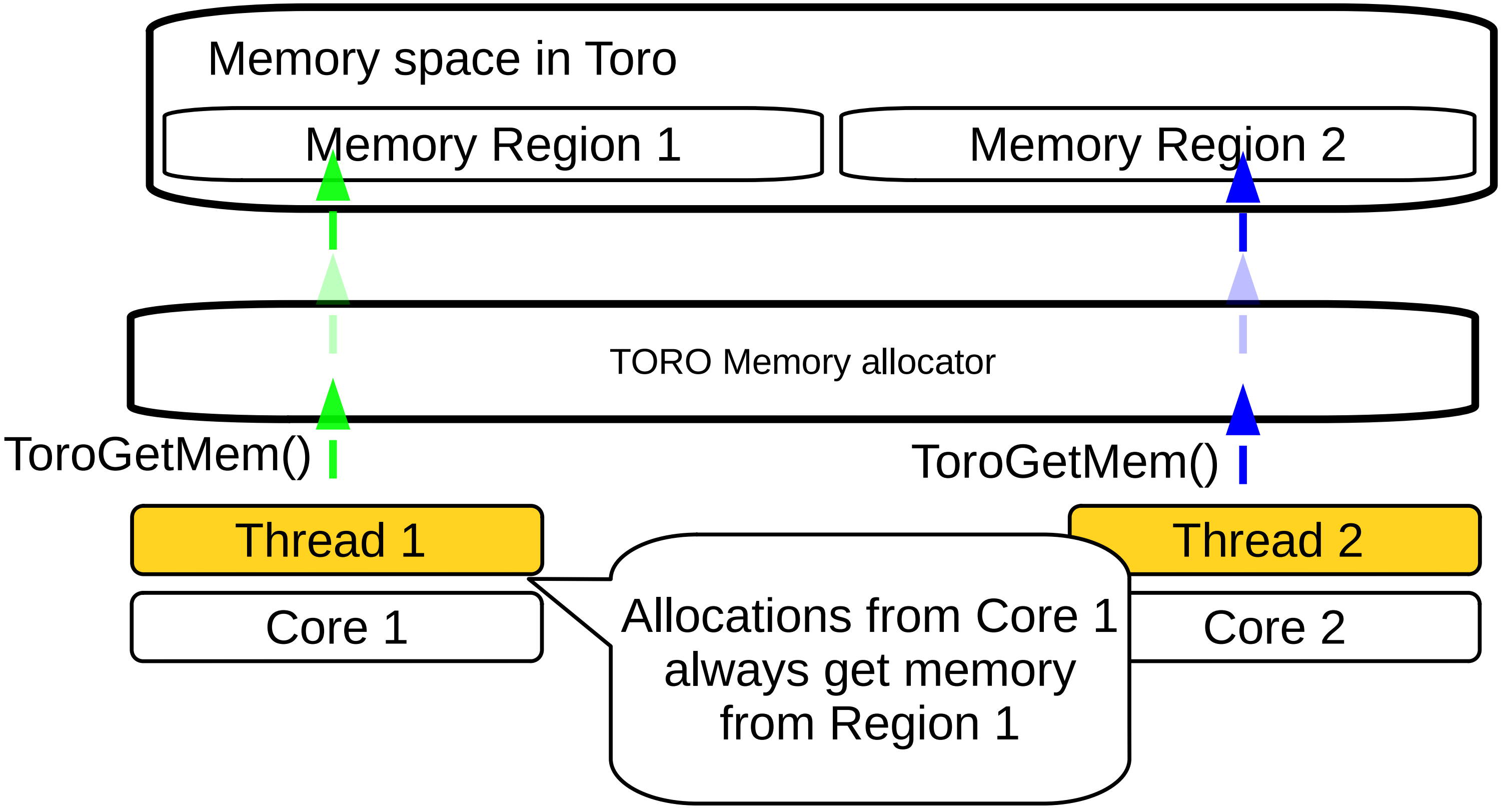

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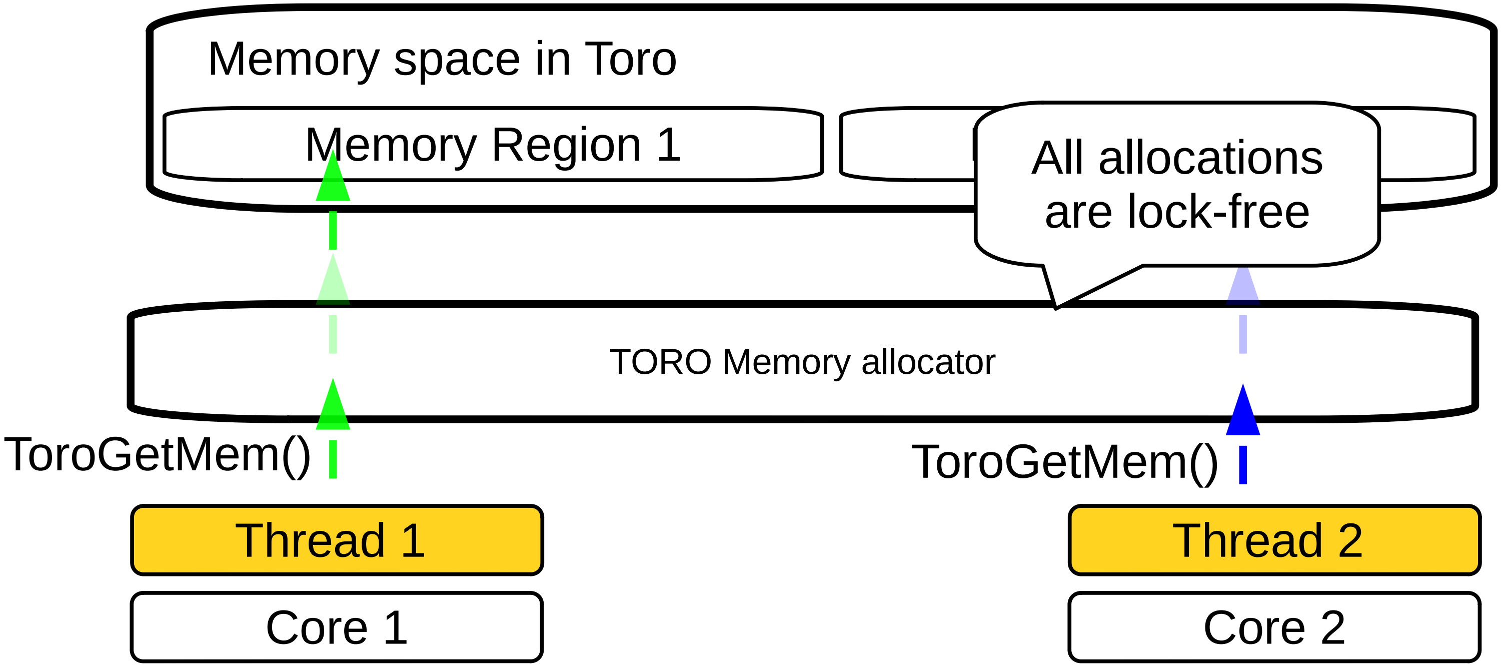
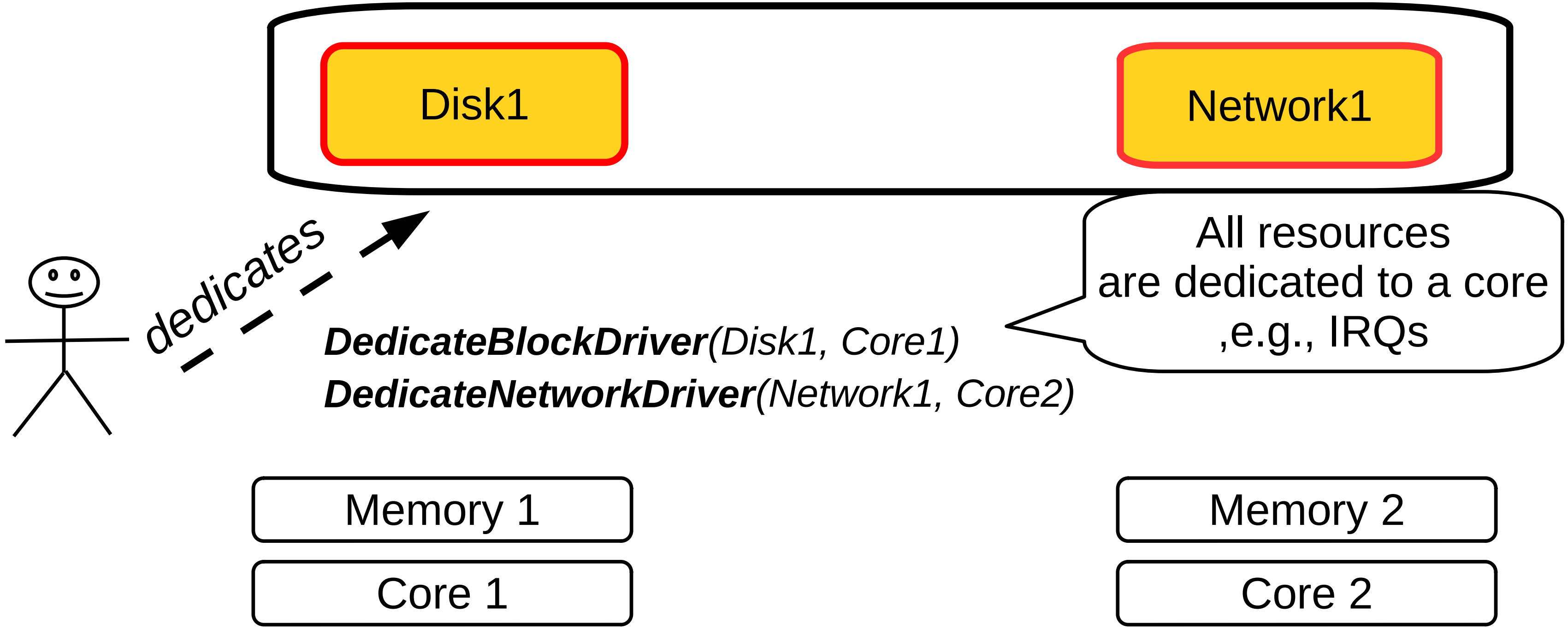
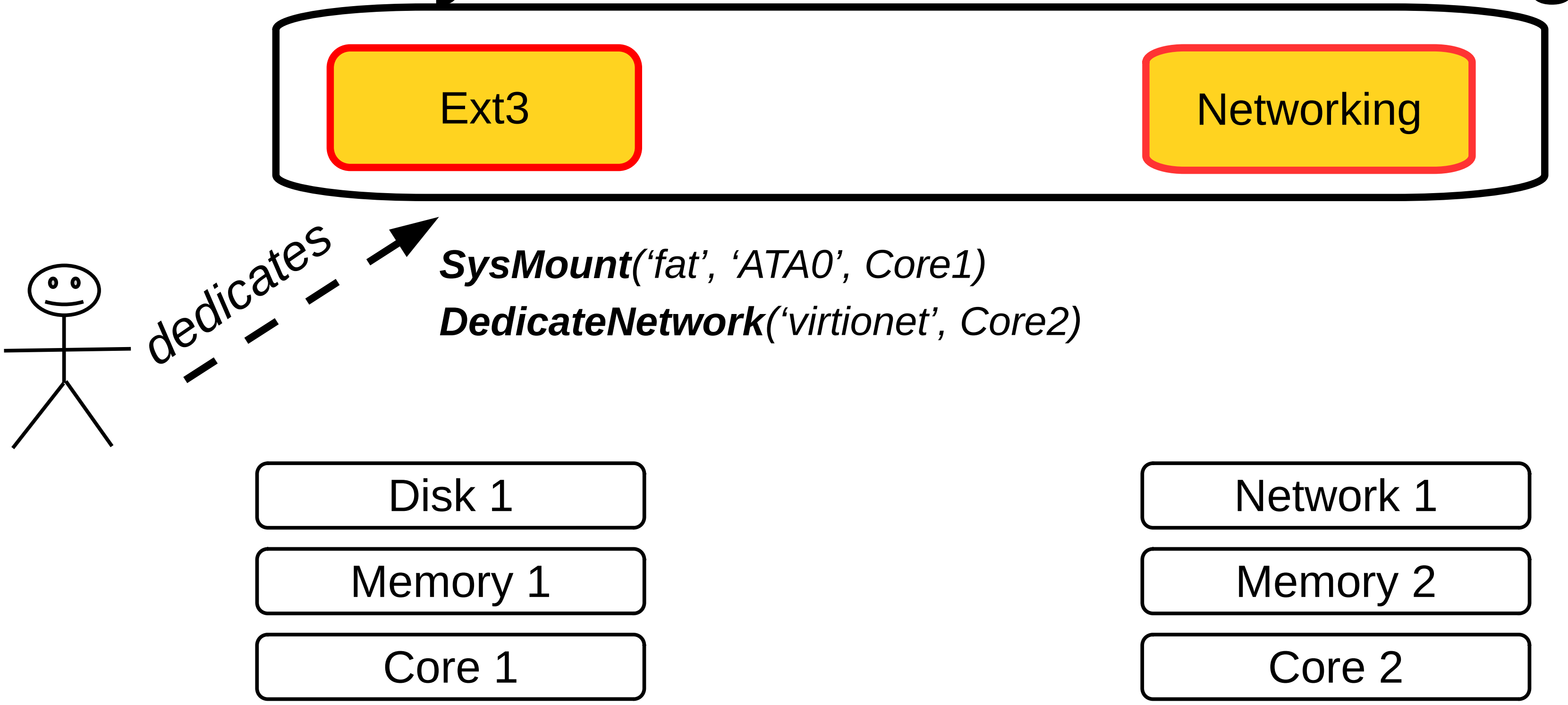


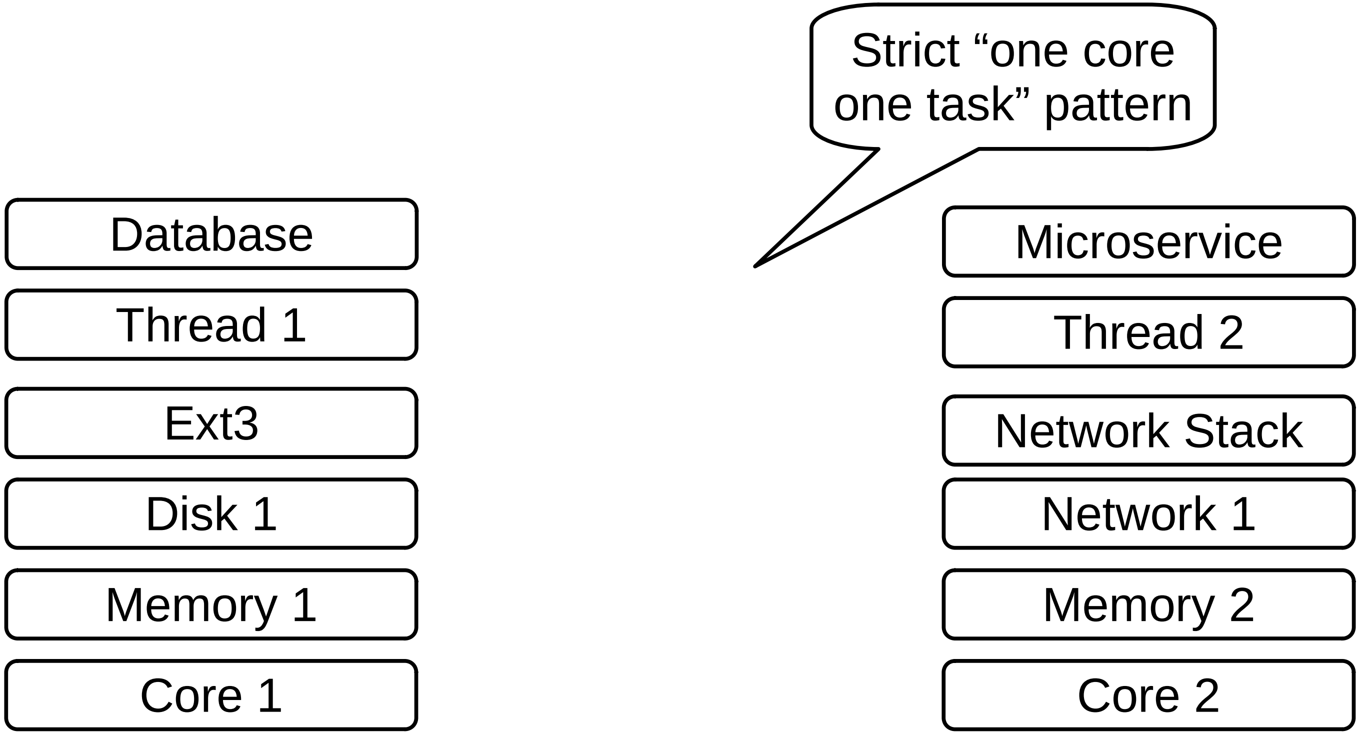
Dedicated Resources
Devices



Dedicated Resources
Filesystems and Networking



Dedicated Resources Filesystems and Networking



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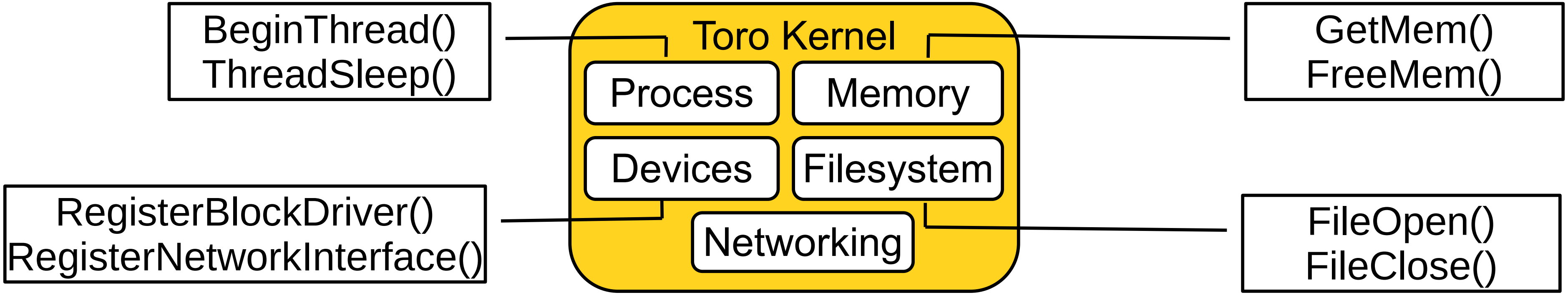
Application-oriented Kernel

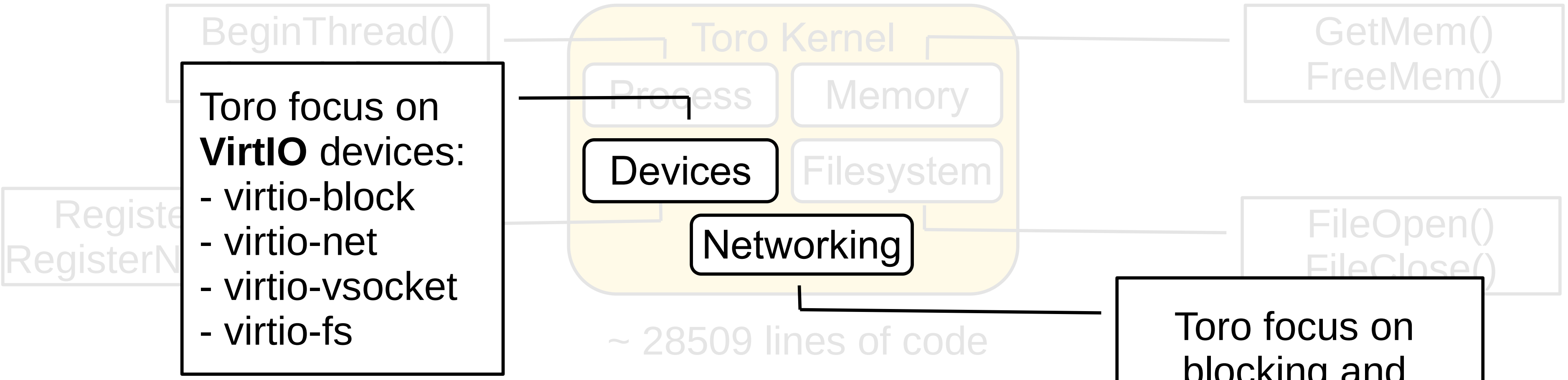


~ 30 KLOC

Toro is an embedded kernel including five units:
- Process
- Memory
- Filesystem
- Networking
- Devices, e.g., Block Device, Network Device

Each unit provides minimalist APIs accessible from the embedded application

Application-oriented Kernel



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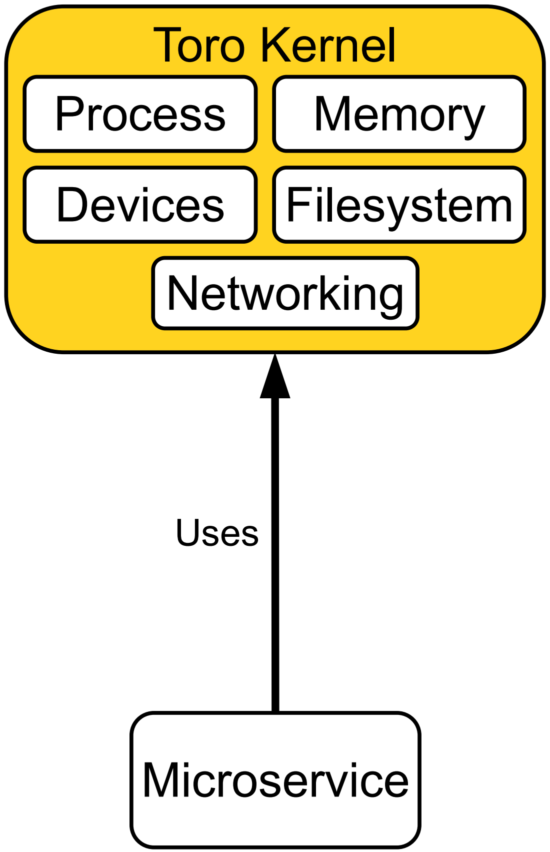
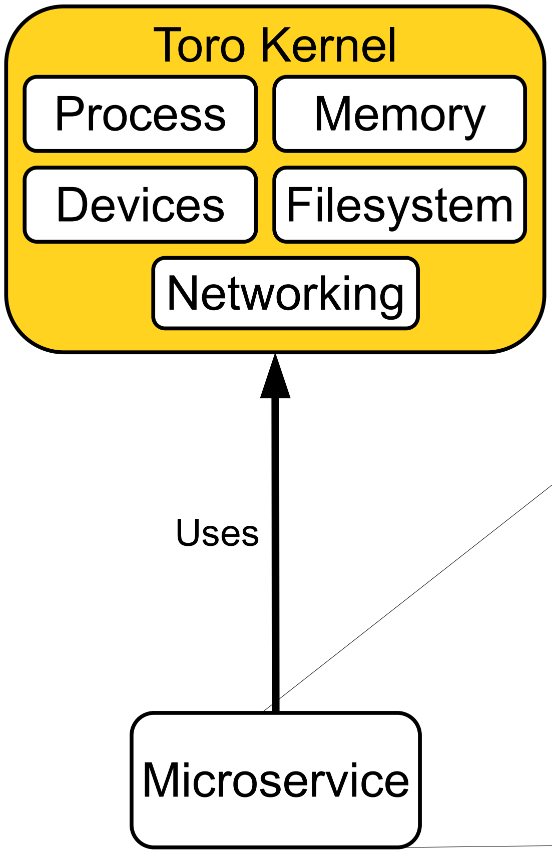


- User application and kernel units are compiled in a single binary
- The application includes only the component required

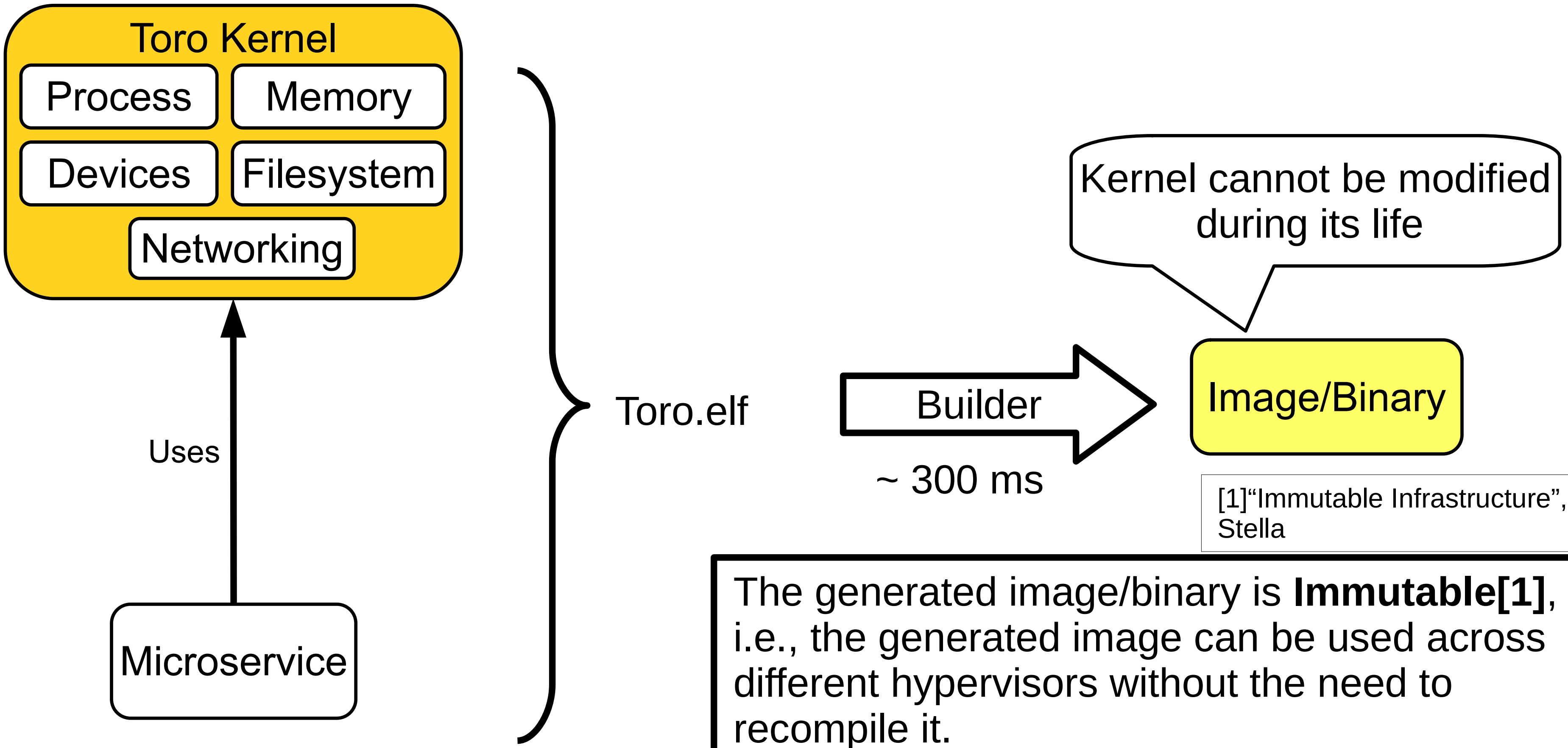
Application-oriented Kernel



- User application and kernel units are compiled in a single binary
- The com

```
program MyMicroservice;
uses
  Memory,
  Filesystem,
  Process,
  Networking,
  Ext3,
  E1000;
Begin
//
// Your Code
//
End.
```

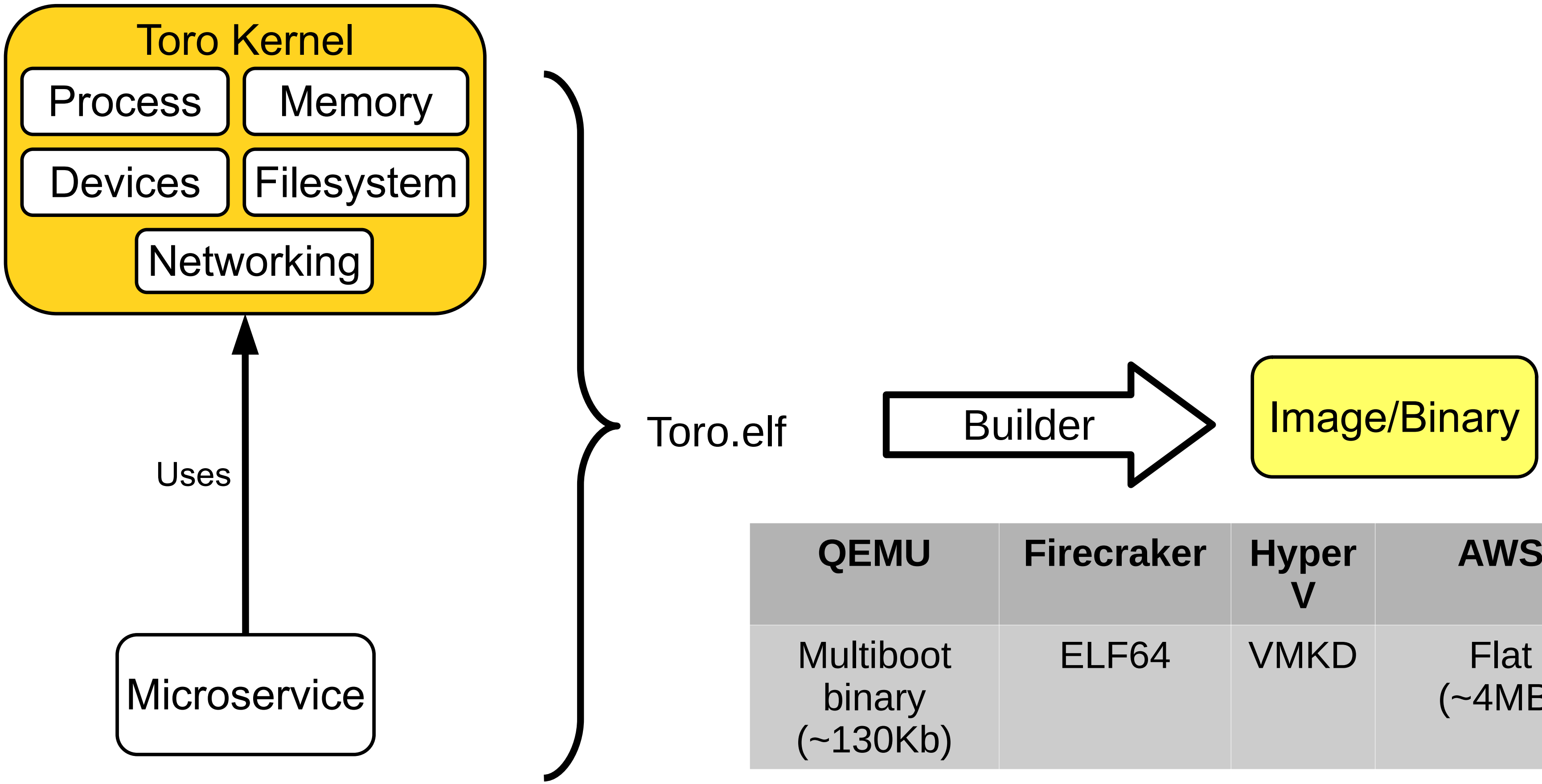
Application-oriented Kernel



[1]“Immutable Infrastructure”, Stella

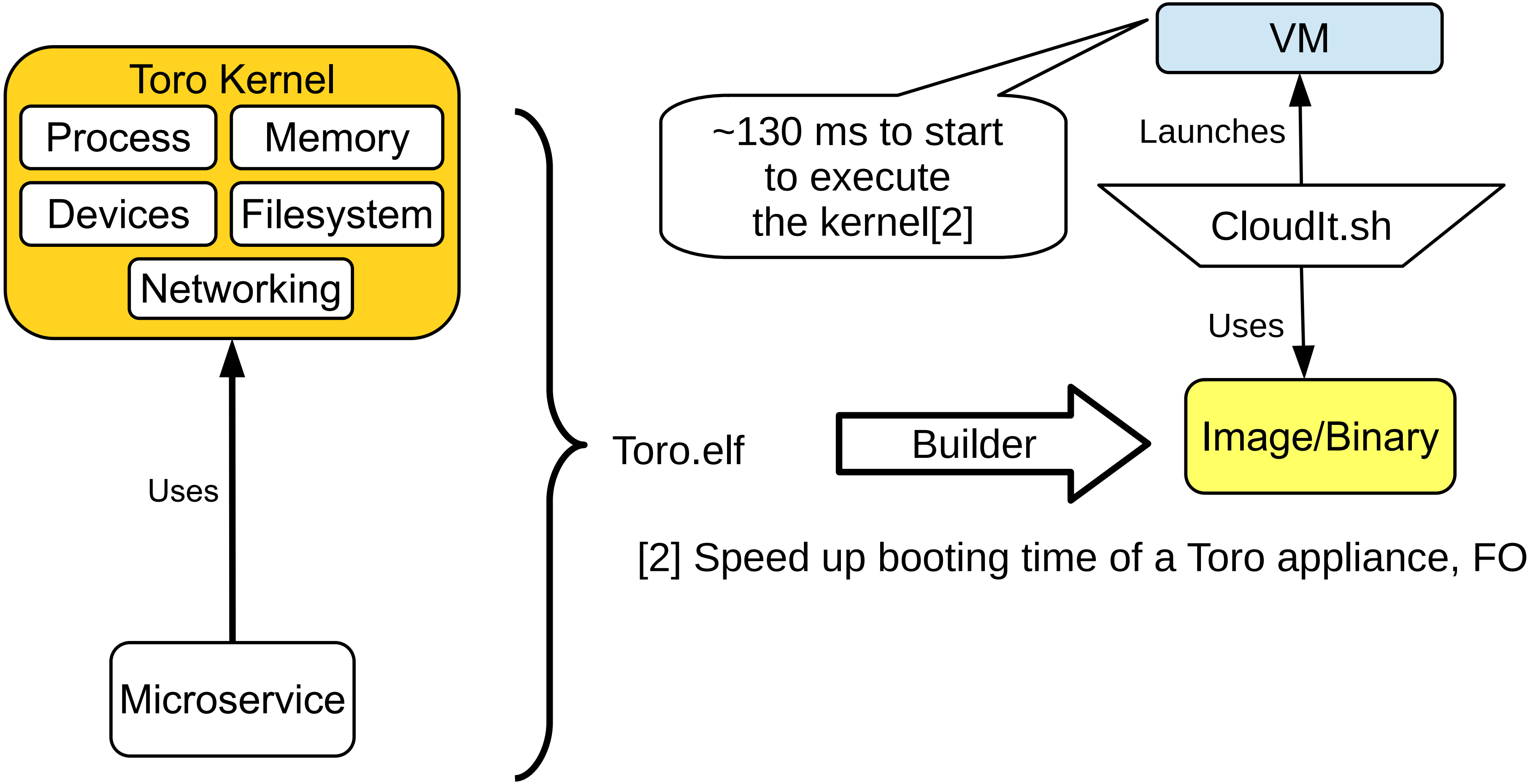
The generated image/binary is **Immutable[1]**, i.e., the generated image can be used across different hypervisors without the need to recompile it.

Application-oriented Kernel



QEMU	Firecraker	Hyper V	AWS	GCE
Multiboot binary (~130Kb)	ELF64	VMKD	Flat (~4MB)	tar.gz

Application-oriented Kernel



[2] Speed up booting time of a Toro appliance, FOSDEM’19

Time until kernel starts to execute

4 cores Intel(R) Atom(TM) CPU C2550 @ 2.40GHz
8 GB of physical memory

Approach	Image (~ 4MB)	Binary (~ 130kB)	Binary with QBoot
QEMU/KVM (2.5.0)	1457 ms	452 ms	132 ms
NEMU (#39af42)		309 ms	95 ms
Firecracker (0.14.0)		17ms	

$ echo “Hello World!”
avg: 2.629263ms

https://blog.iron.io/the-overhead-of-docker-run/

Benefits of Application-oriented Kernel

- Security is based on the hypervisor which ensures a reduced attack surface
- The kernel size is smaller since it only includes the units required for the application
- The smaller kernel size reduces the booting time and eases image manipulation, i.e., your program is your kernel!
- No communication overhead since application is using the kernel APIs

Benefits of Application-oriented Kernel

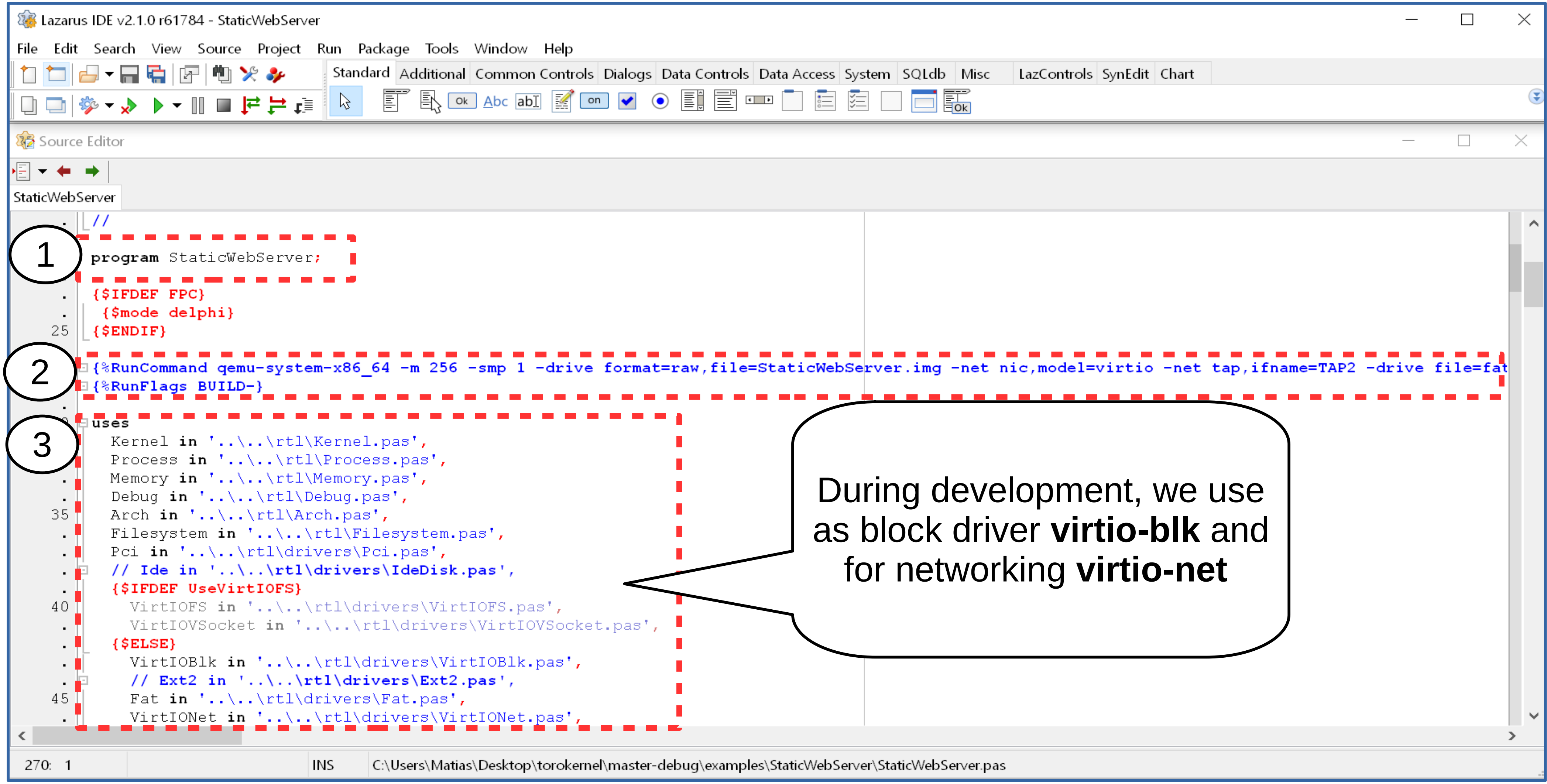
- Security is based on the hypervisor which ensures a reduced attack surface
- Th re
- Th es image manipulation, i.e., your kernel is your program!
- No communication overhead since application is using the kernel APIs

“It’s all talk until the code runs.” - Ward Cunningham

Example: The Static WebServer

- Simple microservice that serves files by using the HTTP protocol
  - https://github.com/torokernel/torokernel/tree/master/examples/StaticWebServer (among other examples ;))
- For development, we base on Windows
- For deployment, we base on a baremetal Linux Host (KVM guest) on Scaleway

Development Workbench



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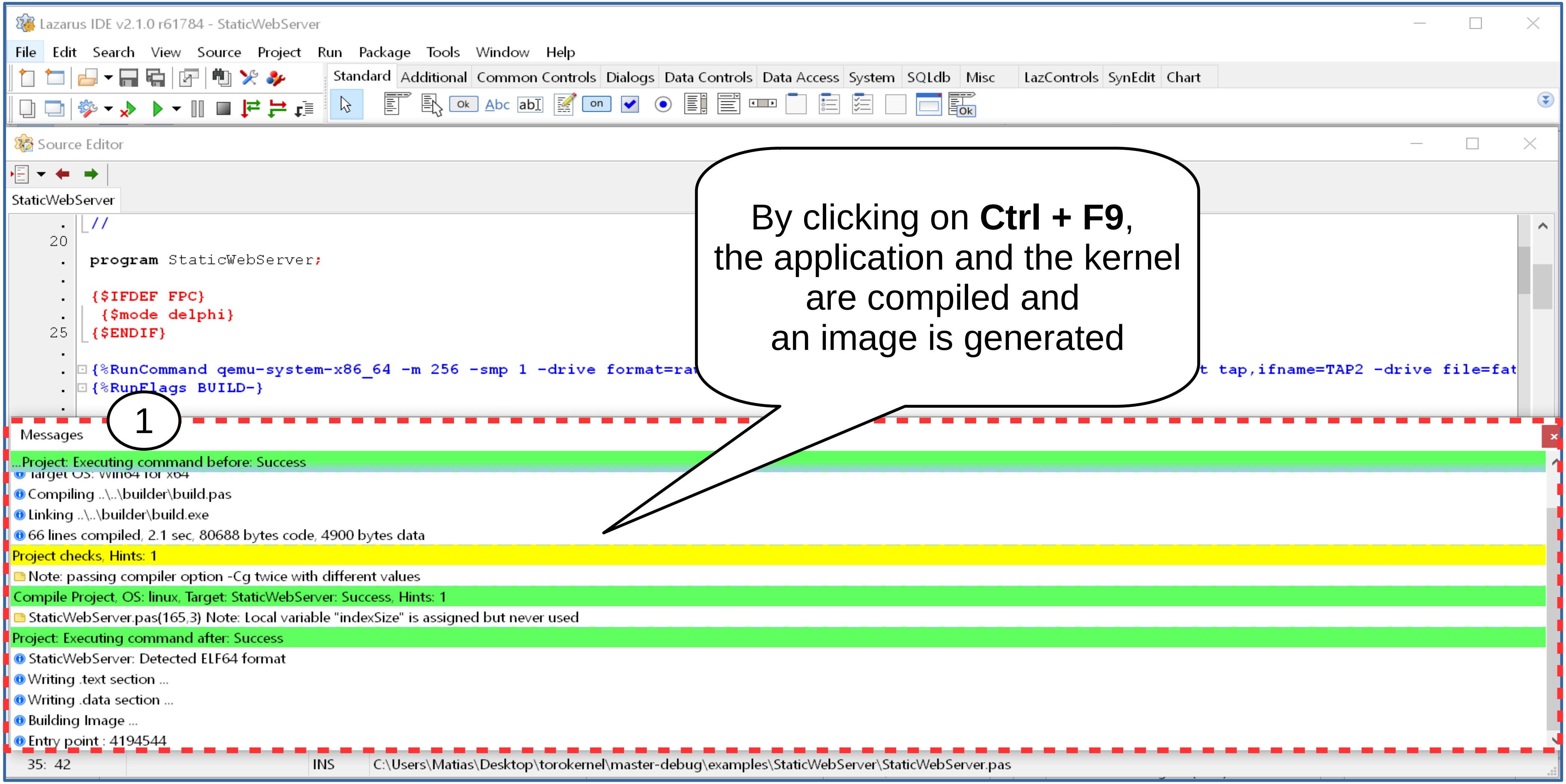
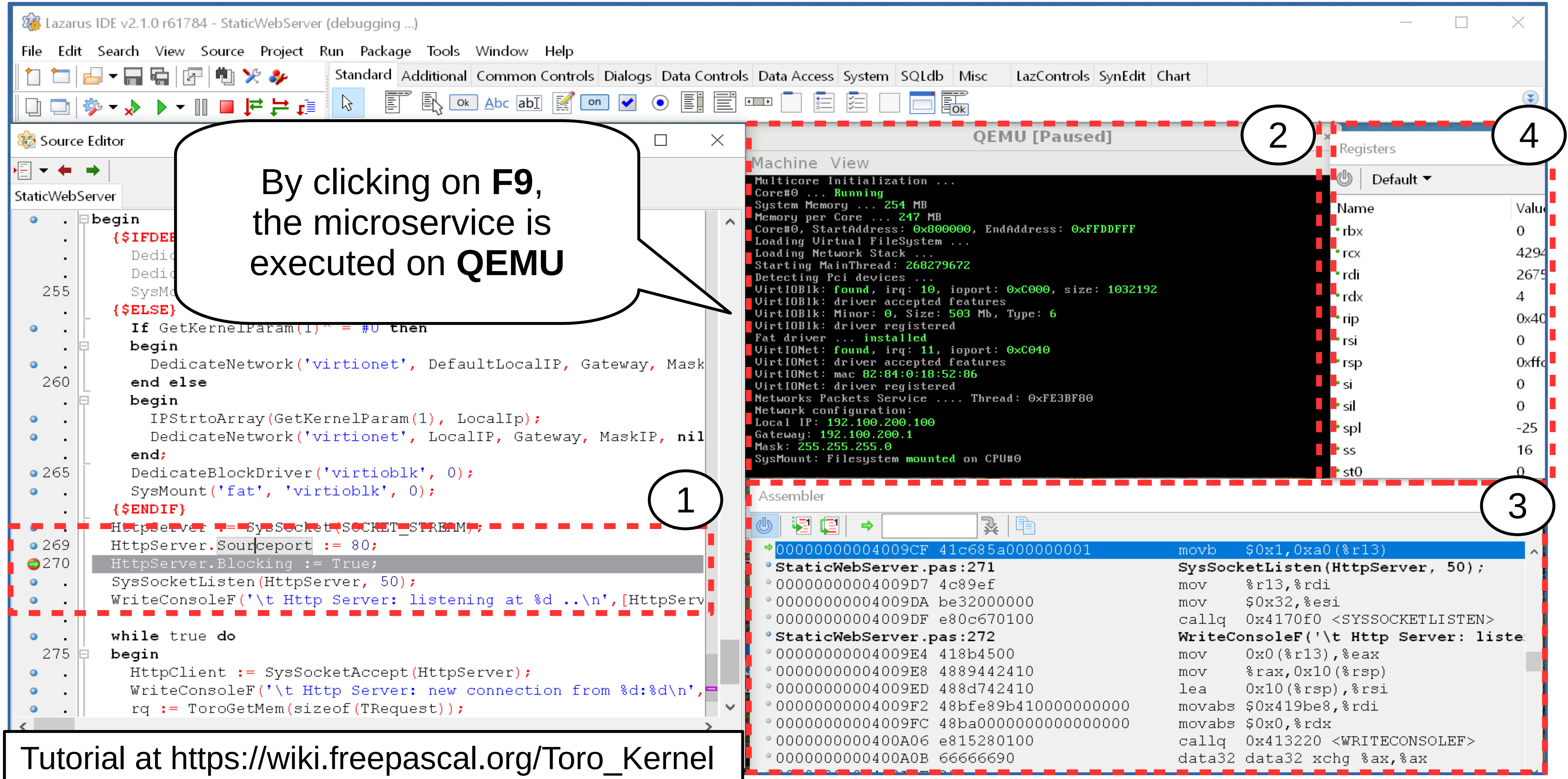


Debugging the kernel from the IDE



Tutorial at https://wiki.freepascal.org/Toro_Kernel

Deployment Workbench

KVM Guest (**Scaleway** Baremetal Host)

$ CloudIt.sh **StaticWebServer** “-append **virtiovsocket,virtiofs,myfstoro**”

```
Booting from ROM..Loading Toro ... HEAD:a990437
Multicore Initialization ...
Core#0 ... Running
System Memory ... 4094 MB
Memory per Core ... 3063 MB
Core#0, StartAddress: 0x800000, EndAddress: 0xBFFDFFFF
Loading Virtual FileSystem ...
Loading Network Stack ...
Starting MainThread: 3221077912
Detecting Pci devices ...
VirtIOFS: Detected device tagged: myfstoro, queues: 1
VirtIOFS: Device accepted features
VirtIOFS: Queue 0, size: 1024, initiated, irq: 11
Fat driver ... installed
VirtIOVSocket: found, irq: 10, ioport: 0xC040
VirtIOVSocket: Guest ID: 3
VirtIOVSocket: RX_QUEUE was initiated
VirtIOVSocket: EVENT_QUEUE was initiated
VirtIOVSocket: TX_QUEUE was initiated
VirtIOVSocket: driver registered
Networks Packets Service .... Thread: 0xBE83BFA8
DedicateNetworkSocket: success on core #0
SysMount: Filesystem mounted on CPU#0
26/10/2019-21:07:33 Http Server: listening at 80 ..
```

Check on http://www.torokernel.io

Summary

- Toro design is improved in five main points:
  - Booting time and building time
  - Kernel API with zero overhead function call
  - Access to shared memory
  - Networking
  - CPU usage

Future Work

- Improve tooling to build, test and debug microservices
- Investigate new use-cases
- Port networking applications to provide starter kits: SMTP relay, HTTP proxy, Web tracking
- Investigate the use of microVM technologies, e.g., Firecraker, NEMU.
- Investigate the use of OpenStack to ease the deployment of Toro appliances
- Compare with other approaches, e.g., unikernels, containers [3]

[3] Toro, a dedicated kernel for microservices, OSSummit'18

QA