Challenges in Operating System Design for Future Many-Core Systems

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Snapshot

General-Purpose Computing (GPC)

- General-Purpose Hardware
  - → **Limited parallelism** degree (few cores era)
- **OS** provides **useful** services to applications, e.g.:
  - → Hardware abstraction
  - → (GP) Scheduling of resources (e.g., tasks on available CPUs)
    - – Automatic separation between interactive and batch applications
  - → (GP) Filesystem, I/O and networking
  - → …
- **Applications** mostly **sequential** (with a few exceptions)
  - → Application-level programmers
  - → OS-level (and kernel-level) programmers

Snapshot

High-Performance Computing (HPC)

- Specialized hardware
  - → Vector machines, …
  - → **Massive parallelism** degree
- **OS** constitutes a "**noise**" (or "jitter") to get rid of
  - → Applications often optimized for underlying hardware
- Optimized distributed filesystems
- **Application-specific** distribution and scheduling logic
  - → Assumption of availability of entire system: no need for caring about multiple applications multiplexed on the same system
- HPC programmers are experts of
  - → parallel programming techniques
  - → …

What's new ?

Future Many-Core Systems

- Potentially suitable for both (high-end) GPC, CC and HPC
- Increasing **need** for a **good OS-level support**
  - → data distribution and replication
  - → **workload distribution, load balancing and scheduling**
  - → management of **complex memory hierarchies** and **incoherent shared memory** segments
- **Nowadays OSes** unable to **efficiently** manage **many** cores
  - → Monolithic kernels
  - → **Global in-kernel data structures** (e.g., processes, file-system)
  - → Global in-kernel synchronization spin-locks (e.g., Linux bkl)
  - → Even **fine-grained locking** (e.g., object-level lock) **inefficient**
    - – When **thousands of cores** may potentially compete

What has been proposed ?
(for scalability in # of cores)

Multikernel (and Barrelfish prototype)

- One OS instance per-core
- Any sharing implemented by message-passing between different kernel instances

Partitioning of cores (Corey OS, GenerOS, FOS)

- Application cores
- Kernel/service cores
- For example, a system call becomes a RPC

Application-level control of sharing (Corey OS)

- Help the kernel understand what is likely to be accessed by multiple tasks and what cannot
  - → Non-sharing default policy, sharing needs explicit actions

Real-Time Applications

Time-sensitive applications

- **Throughput** and/or **latency** constraints
- **Computation times** vary depending on **data locality**
- We don't want to design everything off-line
  - → but we expect to have a **proper run-time OS-level support**
- **Scheduler** needs to be **real-time aware**
- **Adaptivity** plays a key role

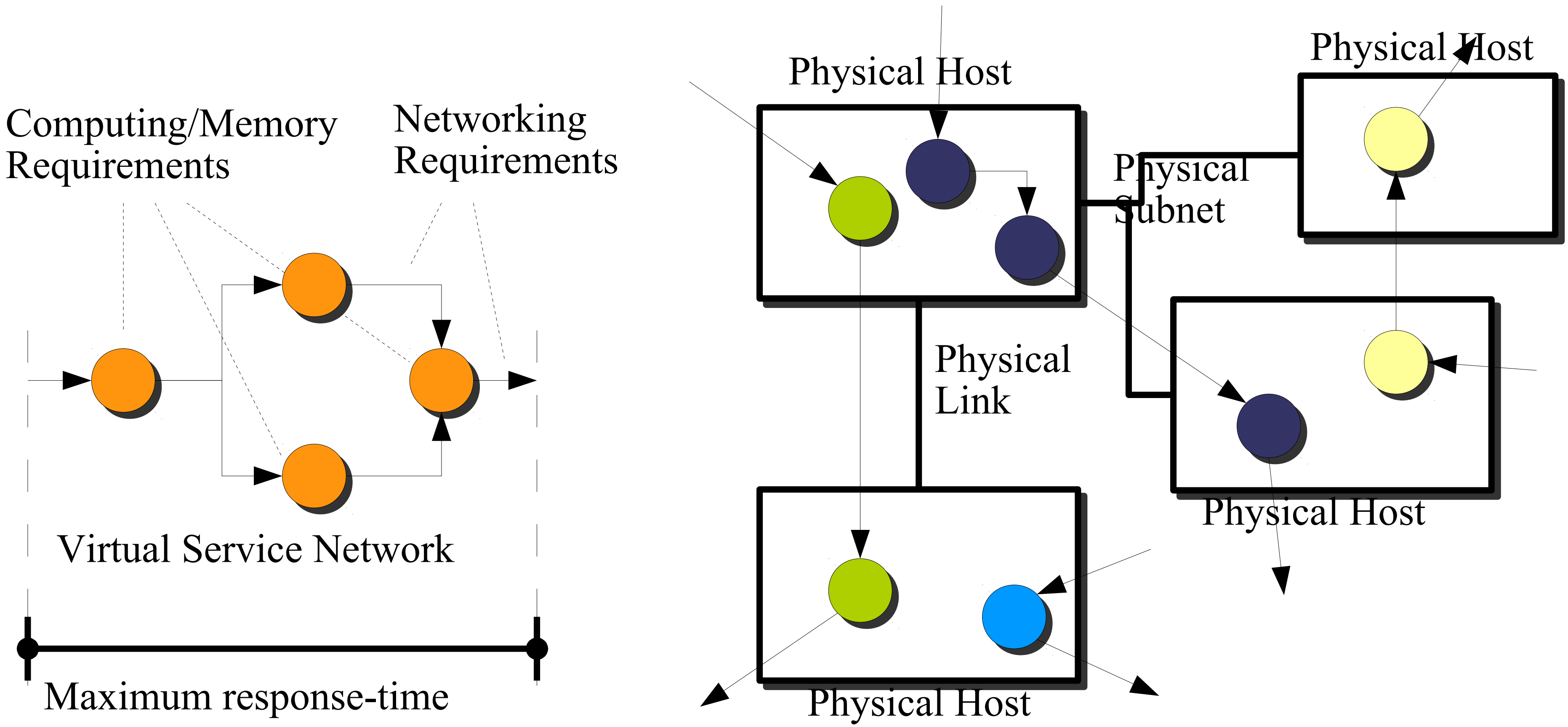
Real-Time Scheduling on Multi-Processors

- Many open problems
- **No known algorithm for efficient use of many CPUs**

Problem presentation

Optimum/reasonable deployment of VSNs on PNs

- Given computing/network/memory requirements
- Respecting end-to-end timing constraints



Scheduling Challenges

Distributed Scheduling Infrastructure

- **No centralized** scheduling decisions
- **Hierarchical management** of resources (and scheduling)
- What properties can we guaranteed system-wide ?

Synchronization and IPC Mechanisms

- More integration with scheduling mechanisms

Application Programming Interface

- What info do we need to expose to the scheduler ?
  - → Application-level DFG and dependencies ?
  - → (expected) Communication paradigms/patterns ?
  - → Timing constraints and (expected) latencies ?
- What info can be **automatically inferred** by the kernel ?
  - → e.g., by (kernel-level) monitoring

More Scheduling Challenges

Heterogeneous Hardware

- Different CPUs have different performance
- How to properly take scheduling decisions ?
- What goals to target ?
  - → maximize system throughput ?
  - → minimize maximum latency ?
  - → minimize energy consumption while keeping timing constraints ?
  - → … ?
- Adaptiveness: when to migrate tasks and how ?
  - → How to deal with the NUMA effect ?

Thanks!