Technische Universität Braunschweig

INSTITUTE OF COMPUTER AND NETWORK ENGINEERING

Challenges of Mapping Real-Time Streaming Applications to General Purpose Manycores

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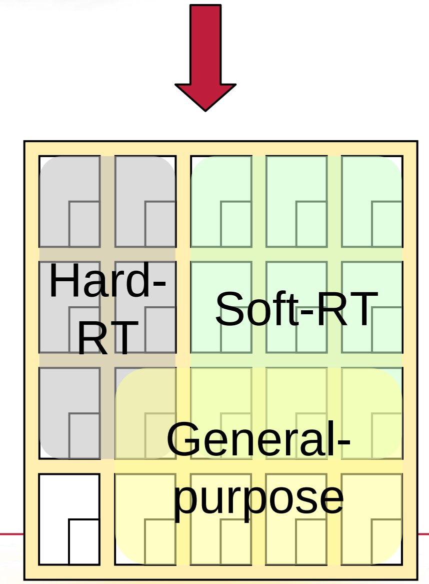
Outline

- Motivation and Introduction
- Resource Management Approach
- QoS Enforcement and Analysis for the NoC
- Conclusion

Motivation

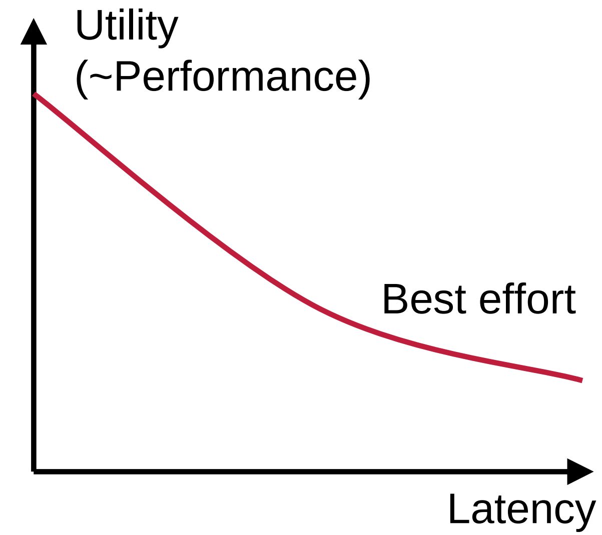
- Goal: Combine
  - Real-time, e.g. augmented reality, SDR
  - Best-effort, e.g. office, games,
  - On general-purpose many-cores
    - Consumer devices (phones, PCs)
- Vision: **“App Store” for real-time applications**
  - Provide guaranteed performance on a multitude of devices
- System-level challenges:
  - Resolve resource conflicts (predictability)
  - Application diversity (throughput vs. guarantees)
  - Applications change at run time

Source: Nokia

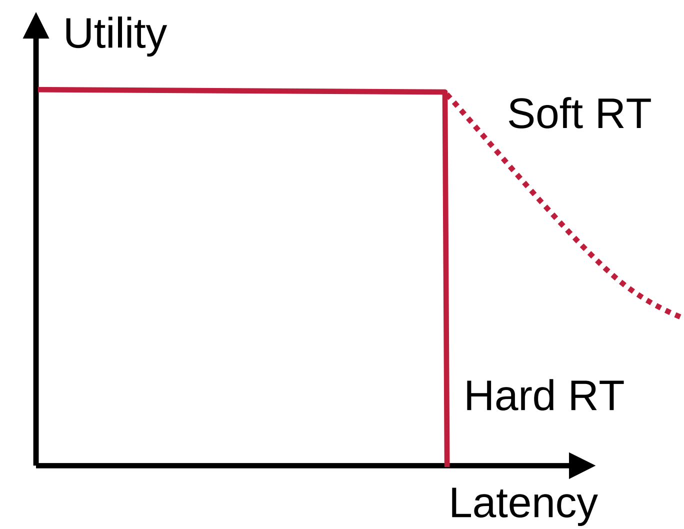


Characteristics of Application Classes

- Best-effort applications
  - Most existing applications, major role in user experience → "first-class citizen"
  - Unpredictable and bursty resource usage
  - **Latency-sensitive**: Application performance degrades with higher latency



- Real-time streaming applications
  - Require resource and timing guarantees
    - Resource sharing must be under control for efficient co-execution
  - Regular access patterns → **Latency-tolerant**: Performance does not degrade with higher latency (up to a certain latency bound)



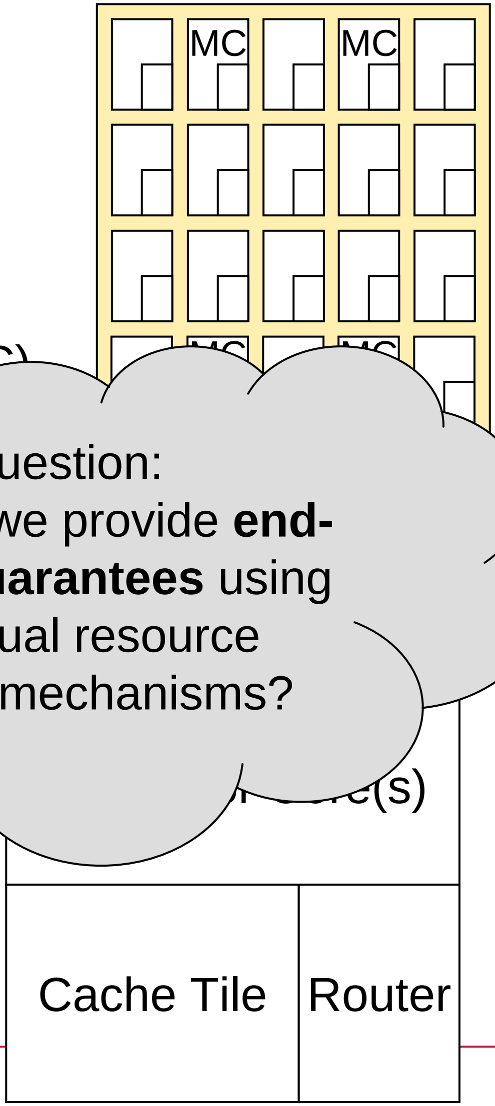
General-Purpose Many-Cores = all shared resources

- Cores
- Packet switched Network-on-Chip interconnect
- Multi-level caches
  - Private L1 (+L2)
  - Distributed shared last-level cache (accessible via NoC)
- Multi-channel off-chip memory

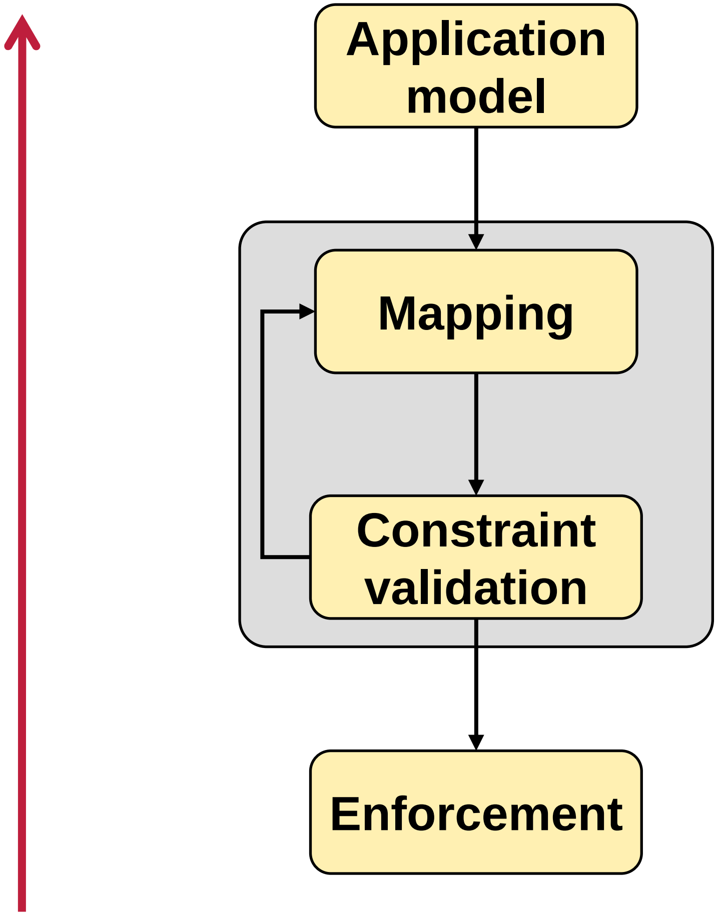
- Currently, resource sharing is mana[…] by first-come first-serve strategies
  ➔ **Infeasible for guarantees!**

Need **predictable resource sharing mechanisms = Platform QoS**

Question:
How can we provide **end-to-end guarantees** using individual resource sharing mechanisms?



Resource Management



1. Applications request resources from resource manager by providing an application model with timing / resource constraints

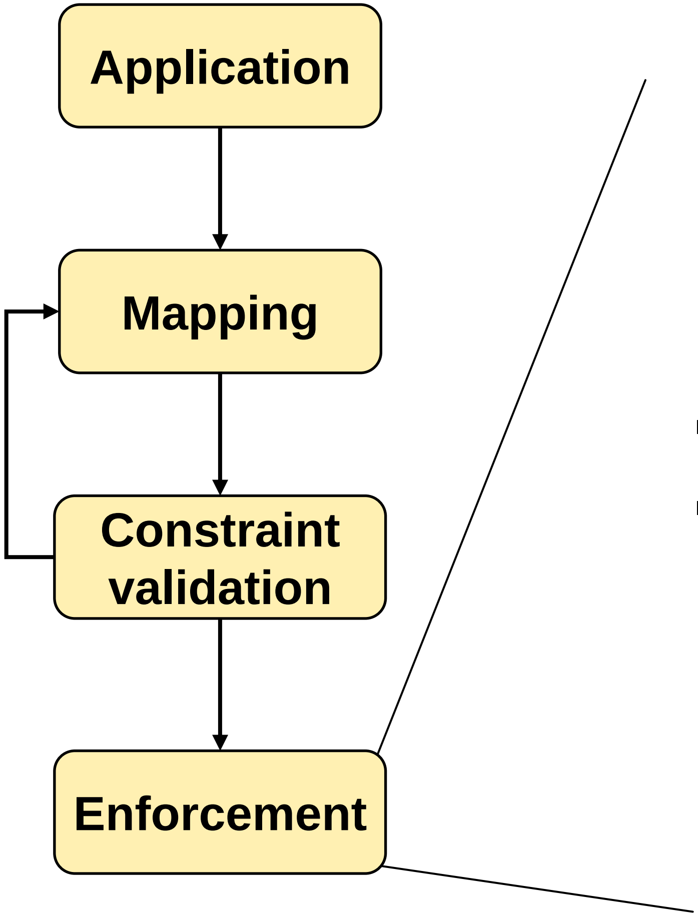
2. Resource manager performs mapping of application model

3. Application constraints and platform limitations are validated
   - Go back to mapping if constraints are not met

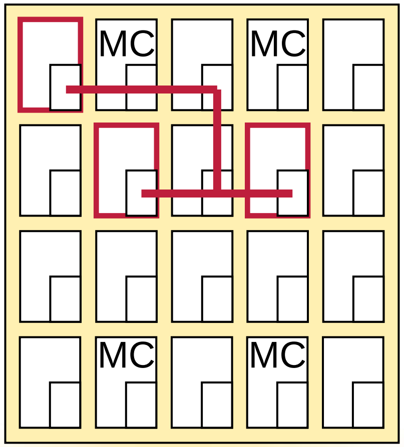
4. Lightweight platform QoS mechanisms for predictability

cf. e.g. [terBraak2010], [Shankar1999]

Resource Management Infrastructure – Enforcement

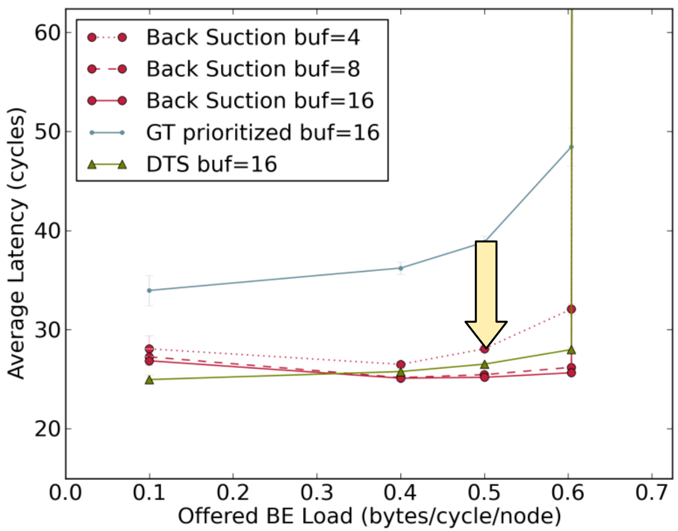


- Individual mechanisms
  - Cores: Scheduling, SMT policy
  - Cache: Address mapping [Cho2007], locking[Vera2003] and/or partitioning [Kim2004]
  - **NoC: Lightweight Throughput Guarantees [Diemer2010a,b]**
  - Memory: Priorities, rate limits [Heithecker2005]
- Controlled by registers, config. messages
- No compromises of BE throughput!



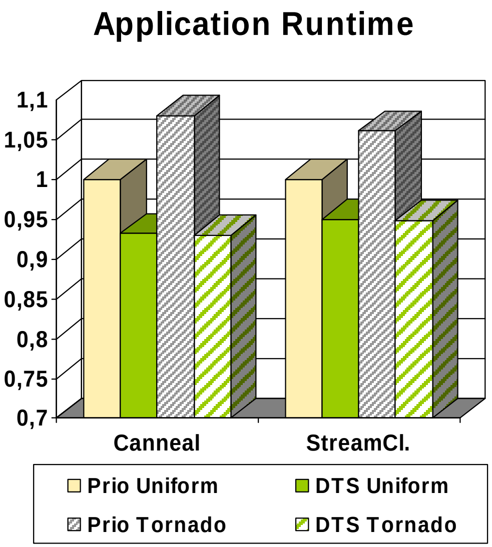
Example: BE-Optimized QoS for NoCs

- Existing mechanisms put BE in background (low priority, idle slots)
- Idea: Exploit latency tolerance of RT streaming applications to improve BE latency
- Approach: Prioritize BE as long as guaranteed throughput (GT) traffic makes sufficient progress → "Back Suction" [Diemer2010b]
  - Progress measured by buffer occupancy (similar to Back Pressure)
  - Prioritize GT **only** if downstream buffer occupancy low



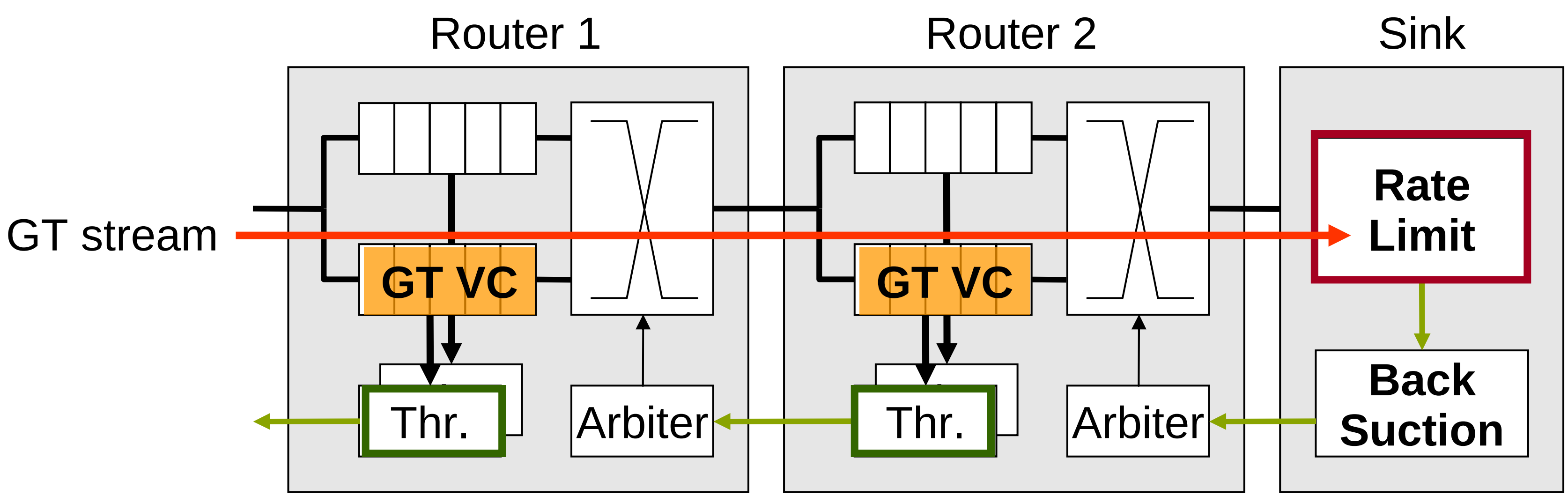
30% latency improvement over standard prioritization scheme

Improve application performance by ~ 10%

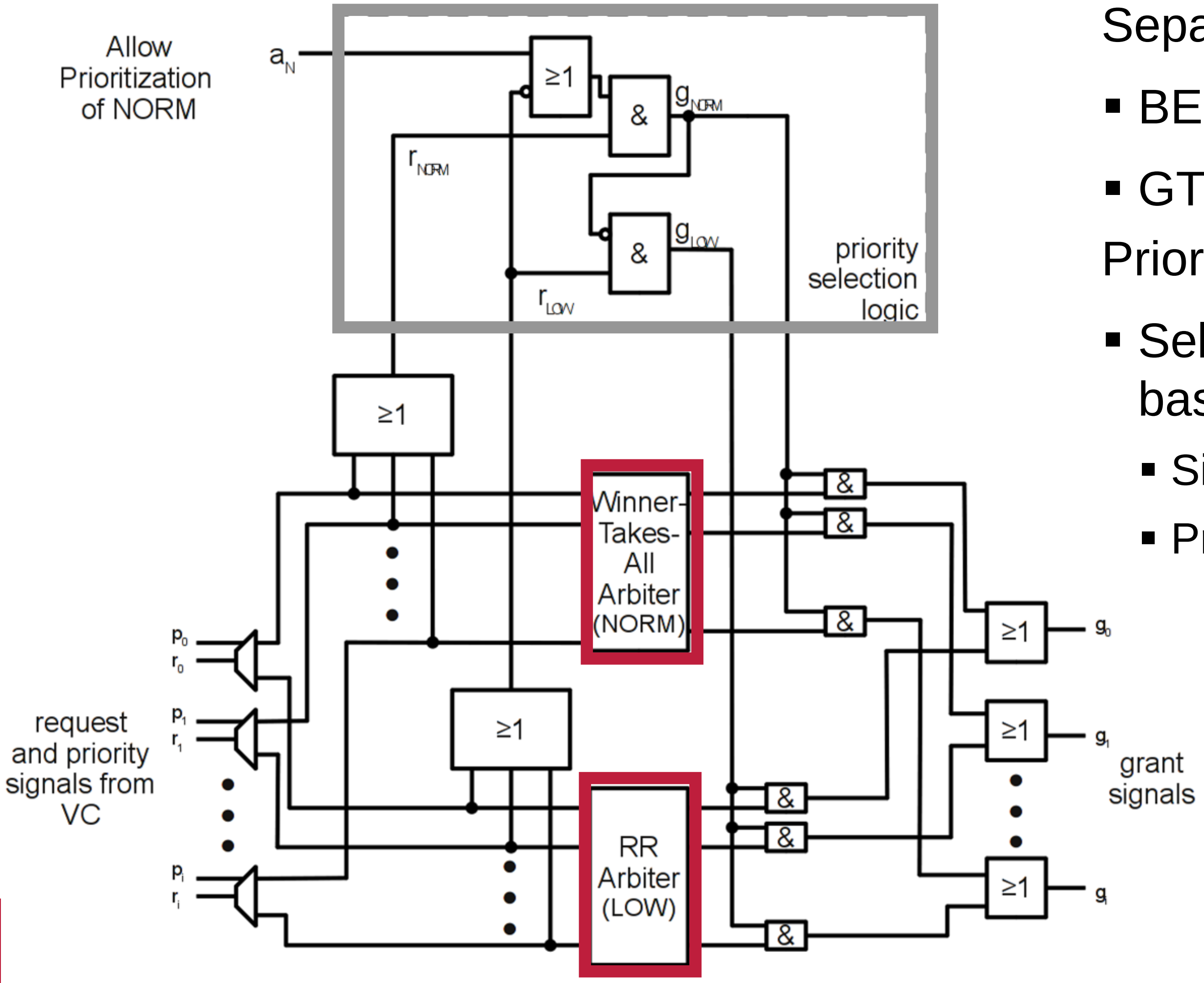


Back Suction Architecture

- Reserve one set of VC (source → sink) per GT stream at run-time
- Limit rate (to guaranteed rate) at which sink may assert back suction
- Threshold Module at every VC
  - Forward back suction signal on low occupancy towards upstream
  - Threshold determines how early prioritization of GT propagates towards sink



Prioritize BE: Selective-Priority Arbiter



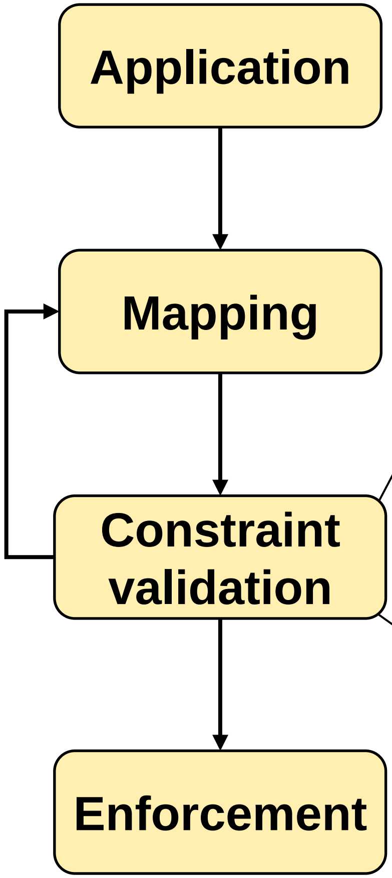
Separate arbiters

- BE: Winner-takes-all
- GT: Round-robin

Priority selection logic

- Select BE or GT based on
  - Signal a_N
  - Presence of BE/GT

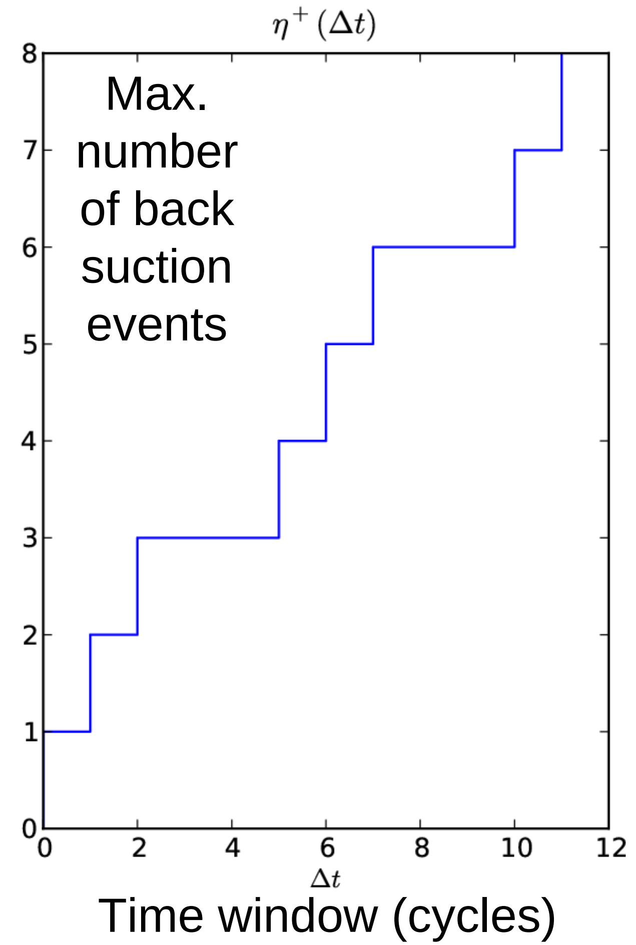
Resource Management Infrastructure – Validation



- Validate timing constraints
  - Overlapping GT streams require scheduling analysis to guarantee individual throughputs
  - Throughput guarantees depend on selection of suction threshold
    ➔ Analysis to determine minimum threshold
- Validate resource availability
  - Number of overlapping GT connections limited by available virtual channels
  - Available VC buffer space must be larger than suction threshold
  - Granularity of guarantees (rate limiter, threshold)

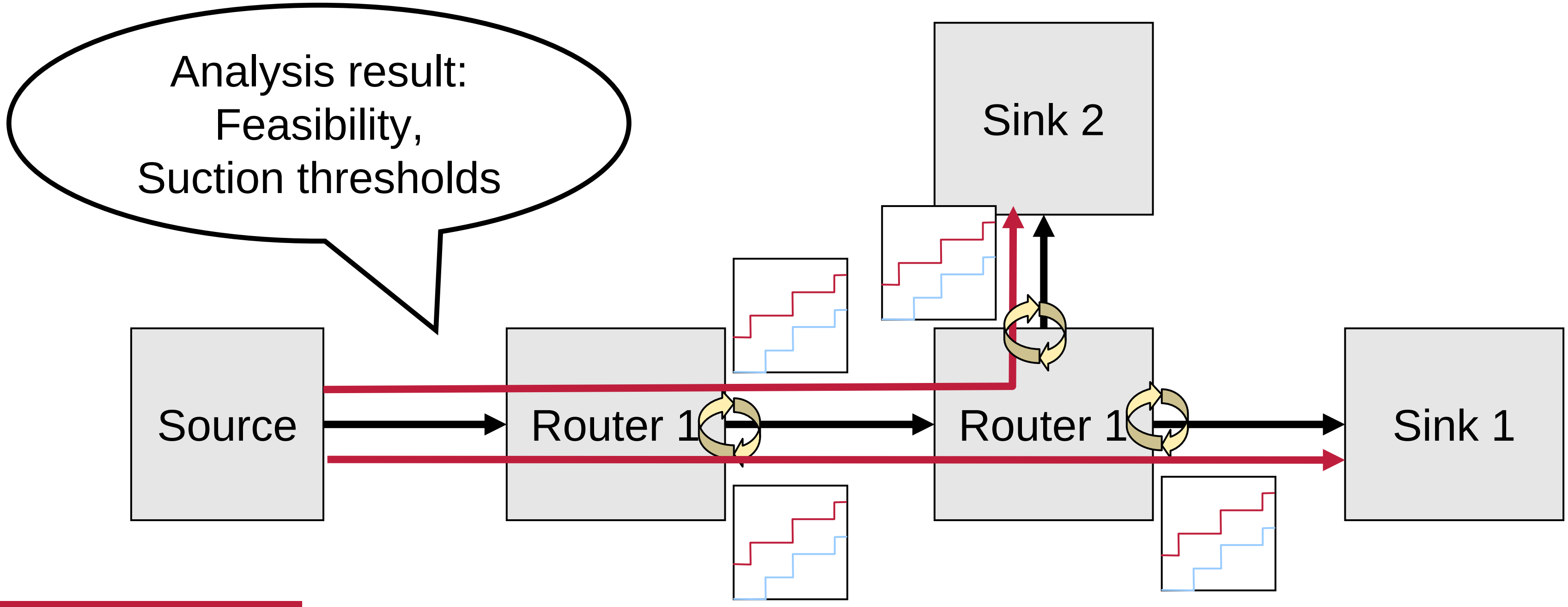
Real-Time Analysis of Back Suction (1)

- Overlapping GT streams share a router output port
- Scheduling analysis (similar to Network Calculus)
  - Stream = task
  - Output port = resource
  - Back Suction = task activation
  - Rate limit at sink = worst case arrival function
- Round-robin analysis at every router:
  ➔ Worst-case service
  ➔ Worst-case backlog
  ➔ Threshold & Worst-case response time
  ➔ Output event model

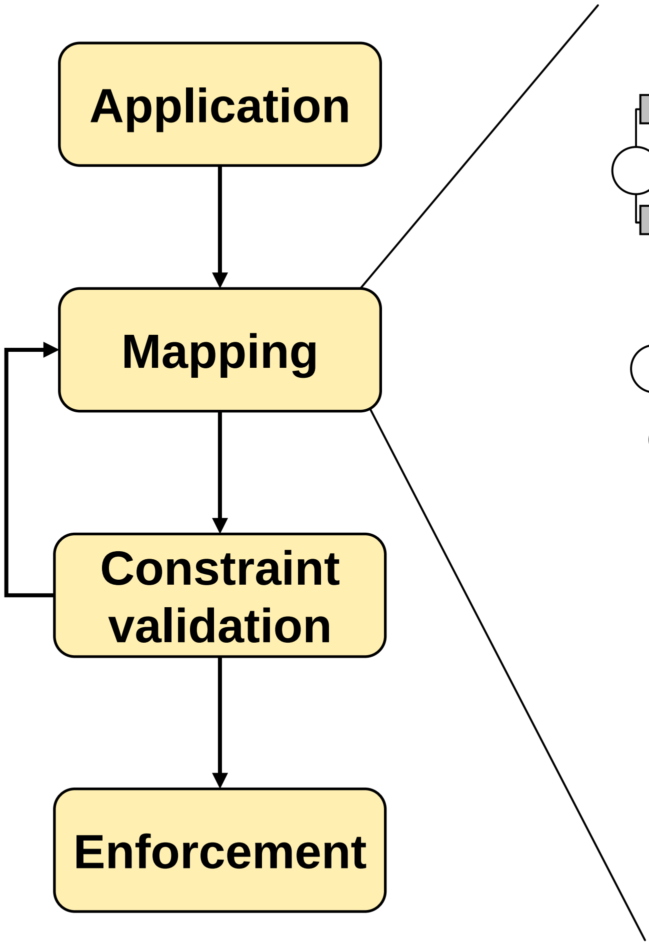


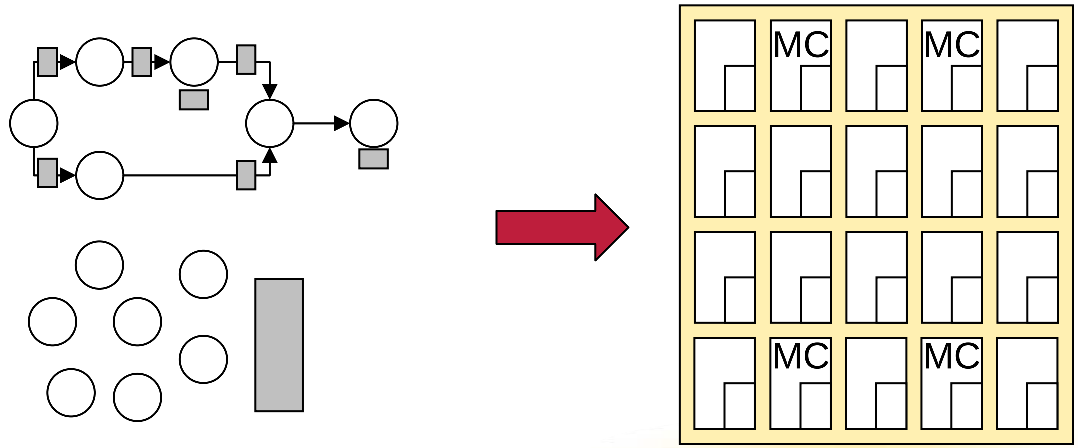
Real-Time Analysis (2)

- Analysis performed on-line as part of the resource management process
  - Analyze at sink first (where we already have an activation model)
  - Propagate models from sinks towards sources
- Analysis time for system ~ 10-100ms (non-optimized python code!)



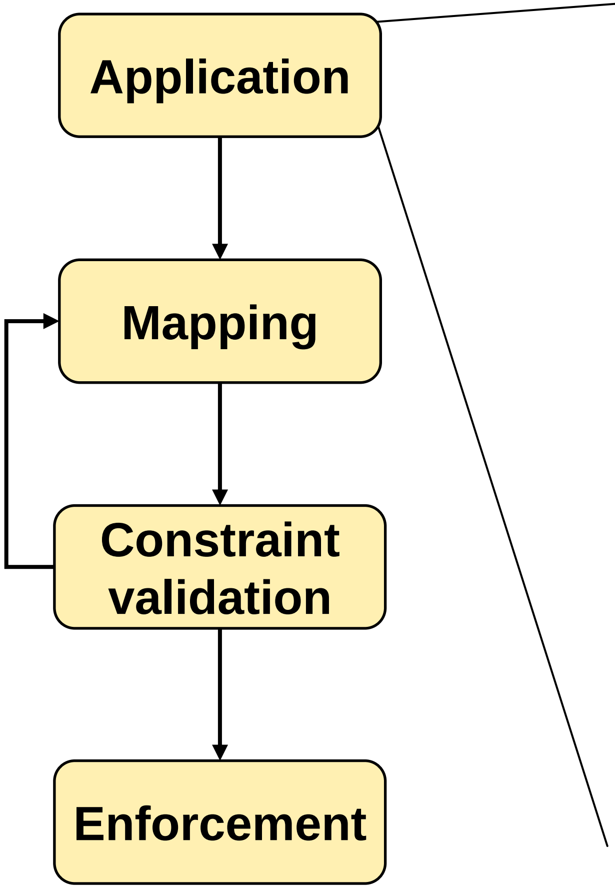
Resource Management Infrastructure – Mapping

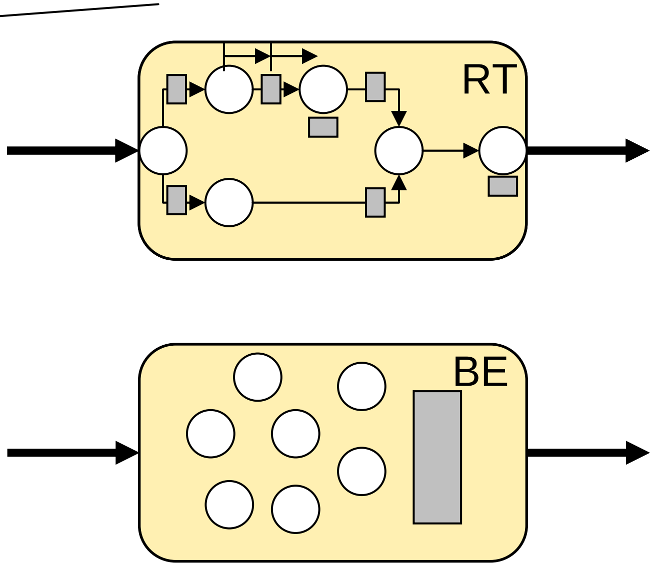




- Map RT applications
  - Tasks → Processing core
  - Communication → GT/GL NoC Links
  - Buffers → Locked/partitioned cache
- Optimization (heuristic)
- Feedback from validation phase

Resource Management Infrastructure – Application Model

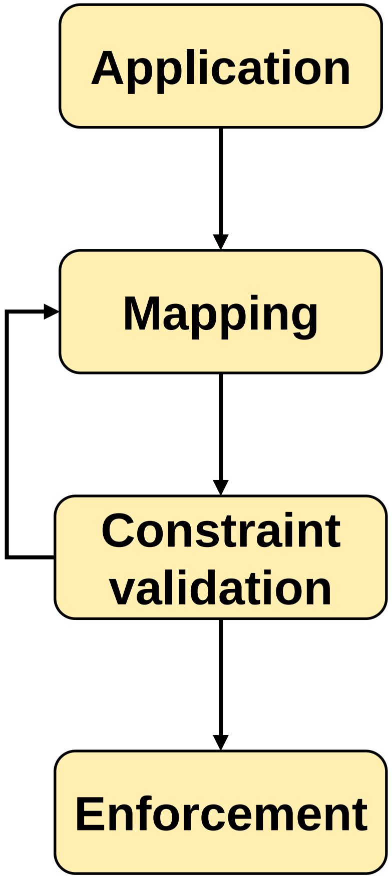




- Request specification: abstract extended DFG model for real-time applications
- Characterization of best-effort applications
  - Obtained from monitoring
  - Optional, to guide mapping heuristics

Conclusion

- Mixing real-time and best-effort applications efficiently is challenging
  - Worst-case predictability vs. best-effort throughput
- Platform with light-weight QoS
  - Predictable sharing mechanisms for individual resources
  - Low overhead and little negative effect on best-effort throughput (e.g. Back Suction)
- Need system-level resource management to
  - Give end-to-end guarantees based on individual mechanisms
  - Overcome resource dependencies
  - Perform run-time mapping
  - Handle limitations of QoS mechanisms



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Thank You for Your Attention!
Questions?

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