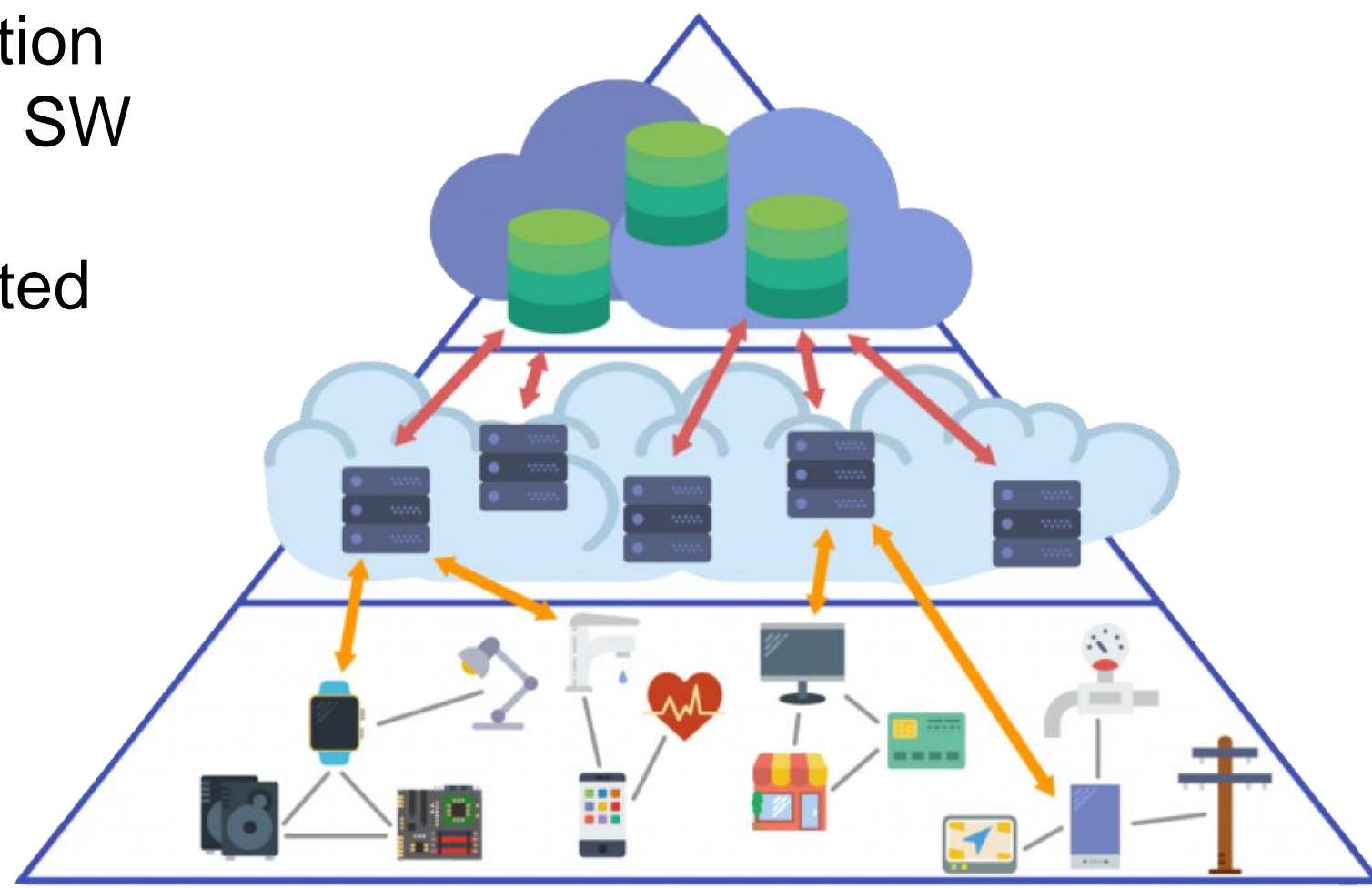


Research context and motivation

- Network Function Virtualization (NFV): decoupling HW from SW
- **Microservices**: cloud-oriented by design, using lightweight general-purpose containers
- **Edge Computing**: move processing power close to the end users



Live Migration

Seamlessly ensure proximity of **latency-sensitive** microservices to mobile end users

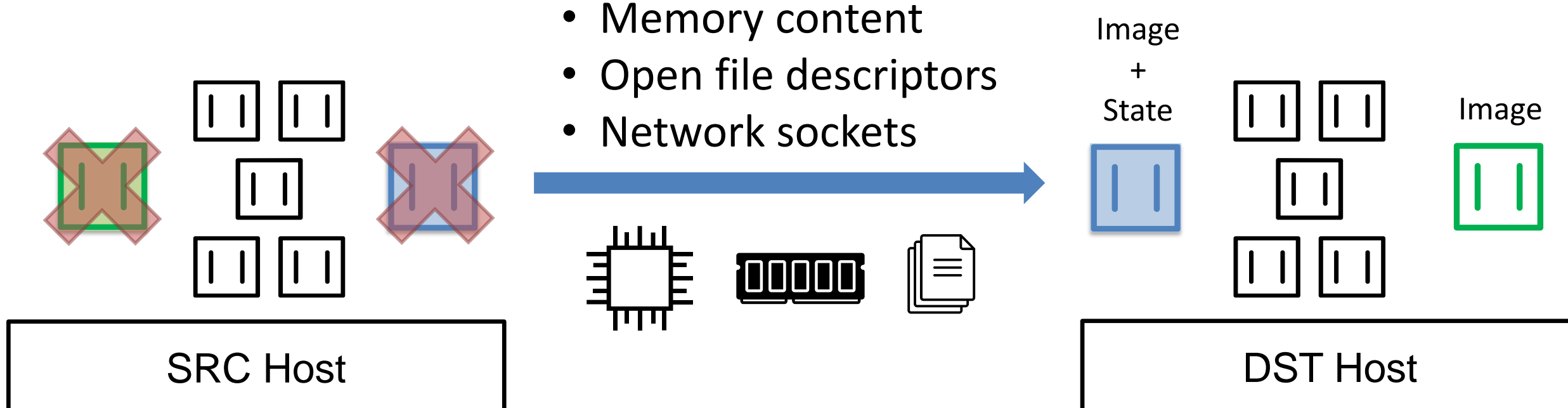
• Dynamic Resource Management Tool:

- » Resource rescheduling
- » Maintenance
- » Fault tolerance
- » Warmup optimization

Addressed research questions/problems

- Stateful migration requires to **keep track of the microservice state**:

- CPU-context state
- Memory content
- Open file descriptors
- Network sockets

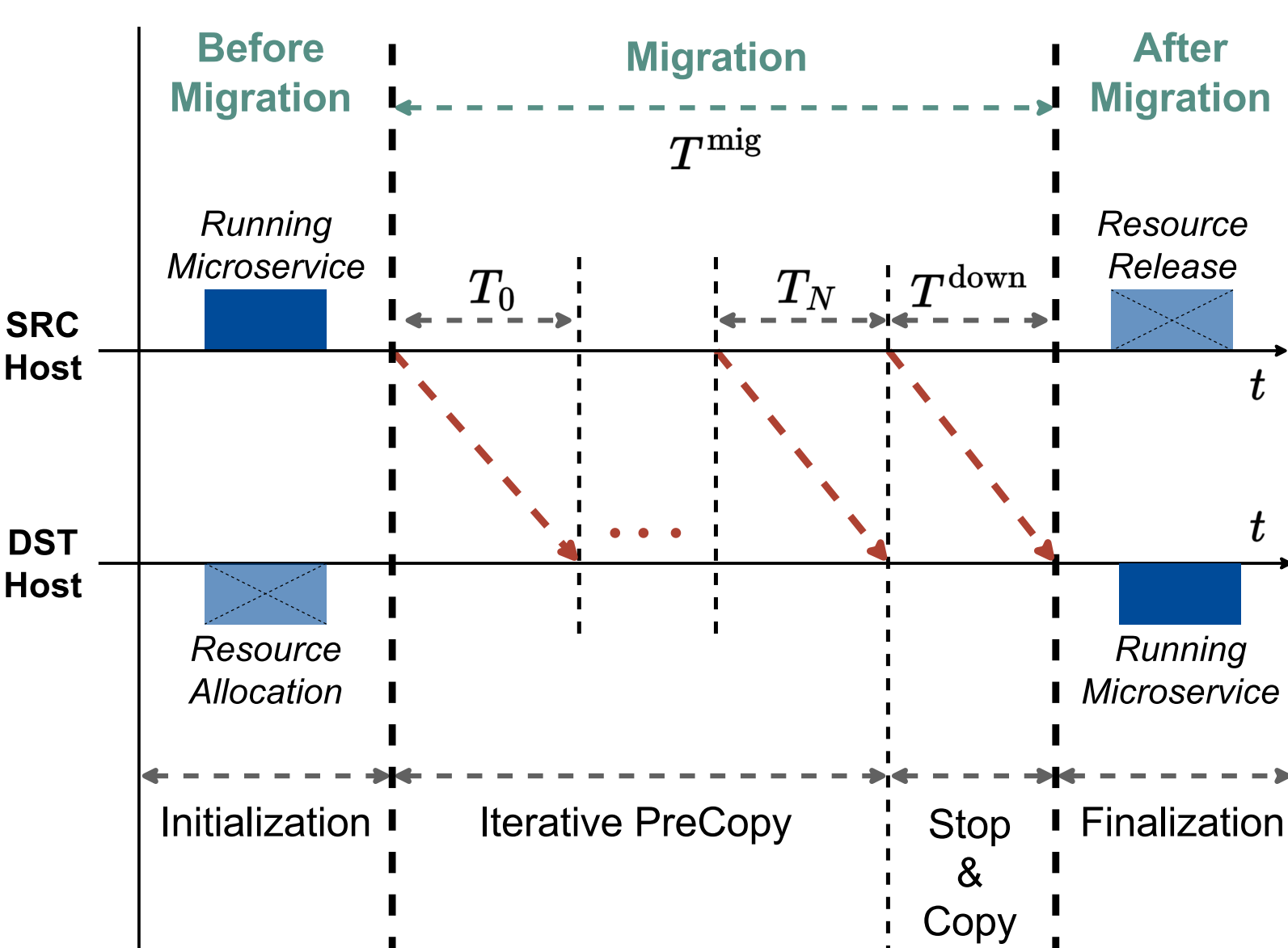


● Stateful Migration

● Stateless Migration

- Lack of **model** for the fundamental KPIs:

- » Migration Duration
- » Downtime



- **Iterative PreCopy** strategy leverages microservice *dirty*ness in memory

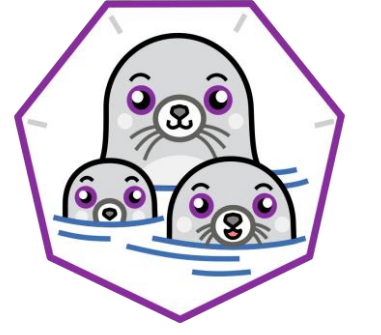
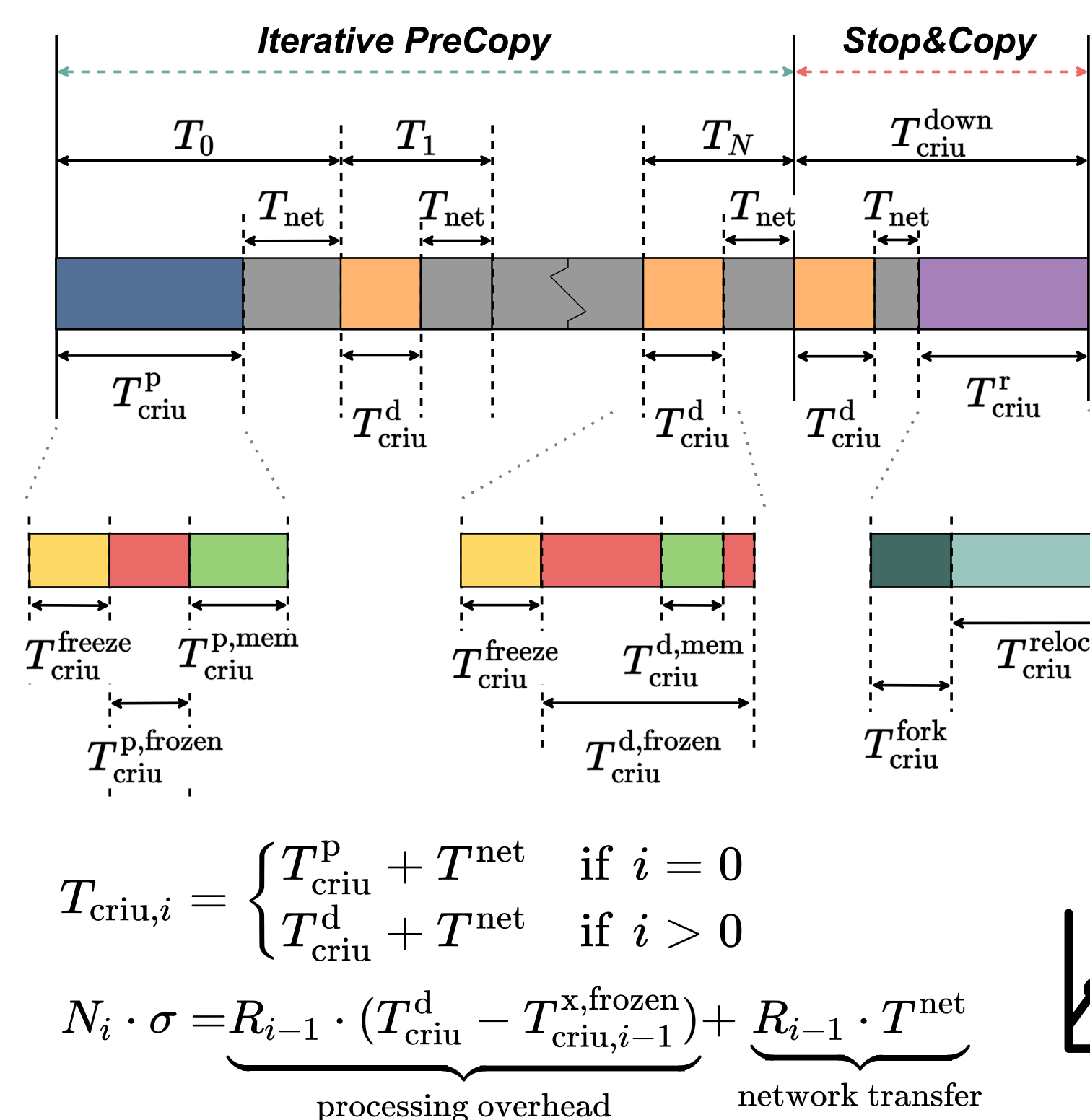
$$T^{\text{mig}} = \sum_{i=0}^I T_i + T^{\text{down}}$$

$$V_i = \begin{cases} \rho(\tau_1 \cdot M + \epsilon) & \text{if } i = 0 \\ \rho(\tau_2 \cdot N_i \cdot \sigma + \epsilon) & \text{if } i > 0 \end{cases}$$

T^{mig}	Total migration duration
T_i	Generic iteration duration
T^{down}	Stop&Copy stage duration
T^p, T^d, T^r	Predump/Dump/Restore durations
$T^{\text{freeze}}, T^{\text{frozen}}, T^{\text{mem}}$	Freezing/Frozen/Memory times
$T^{\text{fork}}, T^{\text{reloc}}$	Forking/Relocation times
V_i	Data volume to be transmitted
N_i	Number of memory pages written
T^{net}	Network time contribution

- The KPIs are function of:
 - » Microservice State Size M
 - » Dirty Page Rate R

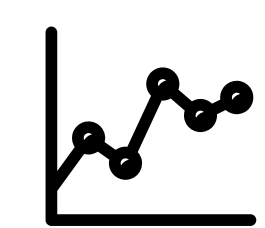
Adopted methodologies



- Experimental **observations** with a synthetic microservice



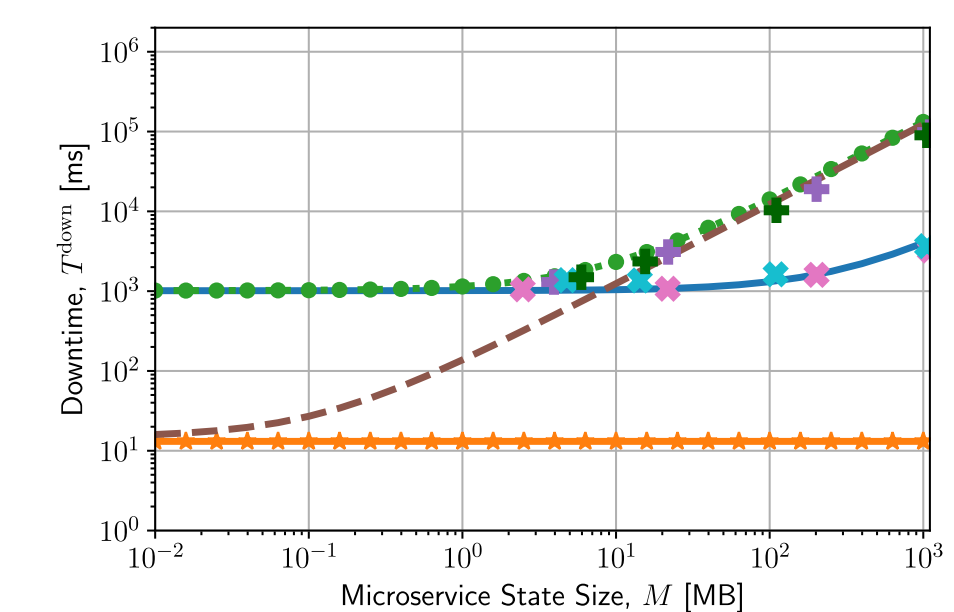
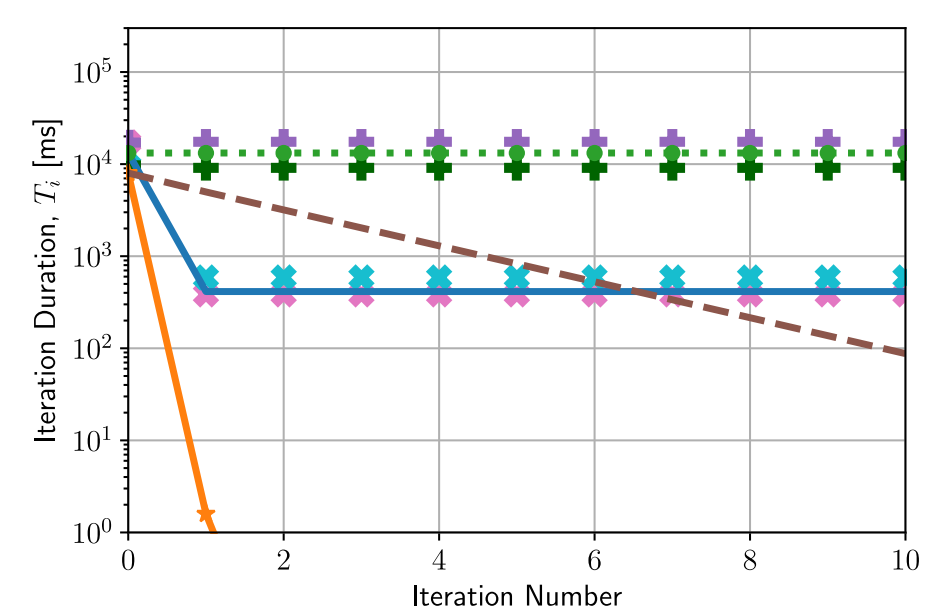
- Model **validation** with renown microservices



- Model **exploitation**
- Comparison with the **StoA [1]** model

Novel contributions

Processing Aware Migration (PAM) Model



- **Accurate** description of migration KPIs
- **Outperforming** SotA [1] model

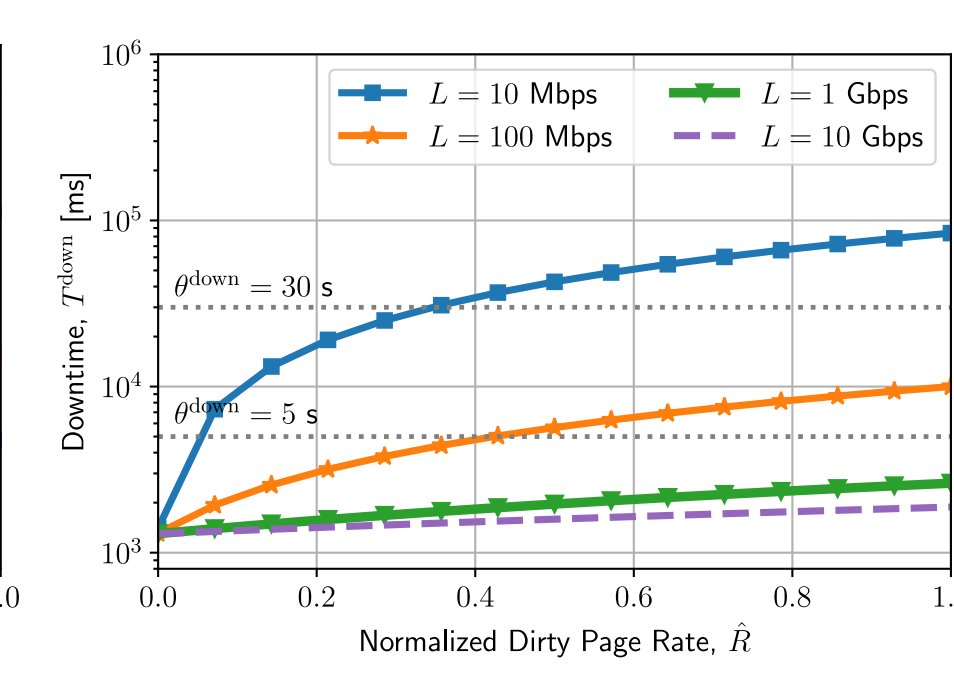
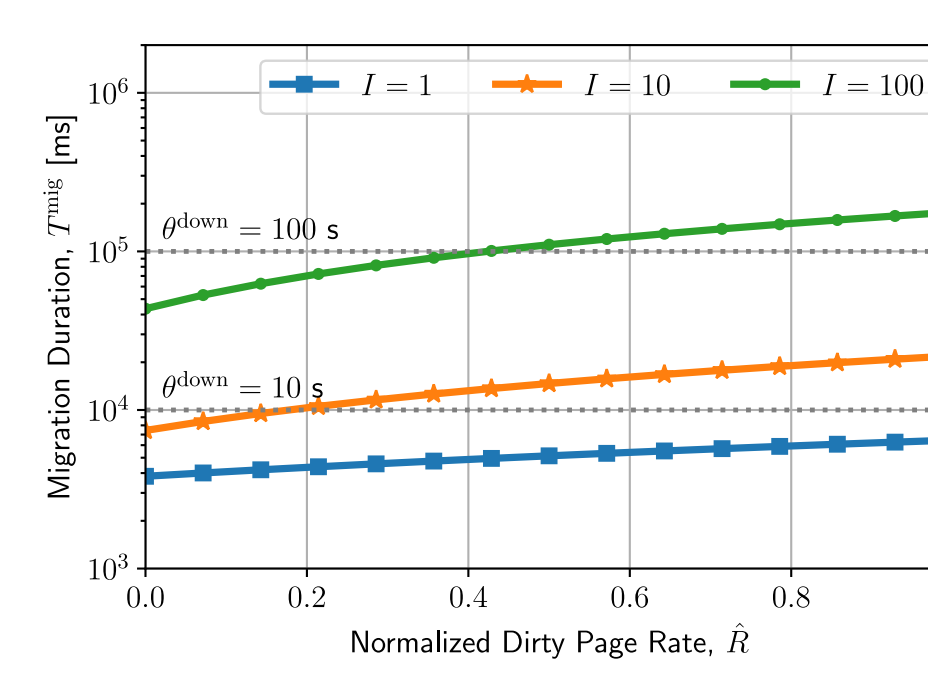
$$L > \frac{V_i(M, R)}{\theta^{\text{down}} - T_{\text{podman}}^d(M, R) - T_{\text{podman}}^r(M)}$$

$$\theta_{\text{min}}^{\text{down}} \approx \alpha_1 \alpha_2 (\beta + \varphi^d) + \alpha_3 \alpha_4 (\psi)$$

$$I = \left\lceil \frac{\theta^{\text{mig}} - T_0(M, L) - T^{\text{down}}(M, R, L)}{T_{\text{podman}}^d(M, R) + T^{\text{net}}(M, R, L)} \right\rceil$$

$$\theta_{\text{min}}^{\text{mig}} \approx \alpha_1 \alpha_2 (\beta + \varphi^p + \delta) + 2\alpha_1 \alpha_2 (\beta + \varphi^d) + \alpha_3 \alpha_4 (\psi)$$

- **Assess feasibility** of migration strategy



- **Design** system according to a deadline
- **Evaluate** min. target values

Future work

- Server-side seamless connection migration » TCP, QUIC, MPTCP
- Integration with container orchestration systems, e.g., Kubernetes
- Leverage CRIU for serverless computing, e.g., λ -functions

List of attended classes

- 01TRARV – Big data processing and programming (01/03/22, 20h, 1.67)
- 01DTPRV – Connected Vehicles (23/06/22, 20h, 1.67)
- 01QTEIU – Data mining concepts and algorithms (03/02/22, 20h, 1.33)
- 01RGRV – Optimization methods for engineering problems (07/06/22, 30h, 1.67)
- 01MNFUI – Parallel and distributed computing (19/09/22, 25h, 1.67)
- 01DNBIU – Security of next generation networks (18/07/22, 22h, 1.67)
- 01PJMRV – Computer Ethics (27/04/22, 20h, 1.33)
- 01QORRV – Writing Scientific Papers in English (24/03/22, 15h, 1.33)
- 02LWHRV – Communication (27/11/21, 5h, 1.33)
- 08IXTRV – Project management (02/01/22, 5h, 1.33)
- 01RISRV – Public speaking (15/01/22, 5h, 1.33)

Submitted and published works

- “Podman-CRIU integration: A comprehensive migration performance evaluation”, in preparation for conference submission
- “Processing-aware Migration Model for Stateful Microservices at the Edge”, in preparation for journal submission

[1] T. He, A. N. Toosi, and R. Buyya, “SLA-aware multiple migration planning and scheduling in SDN-NFV-enabled clouds,” *Elsevier, Journal of Systems and Software*, 2021.

