Michele TORTELLI
Dario ROSSI
Emilio LEONARDI

TELECOM ParisTech

Model-Graft: Accurate, Scalable and Flexible Analysis of Cache Networks

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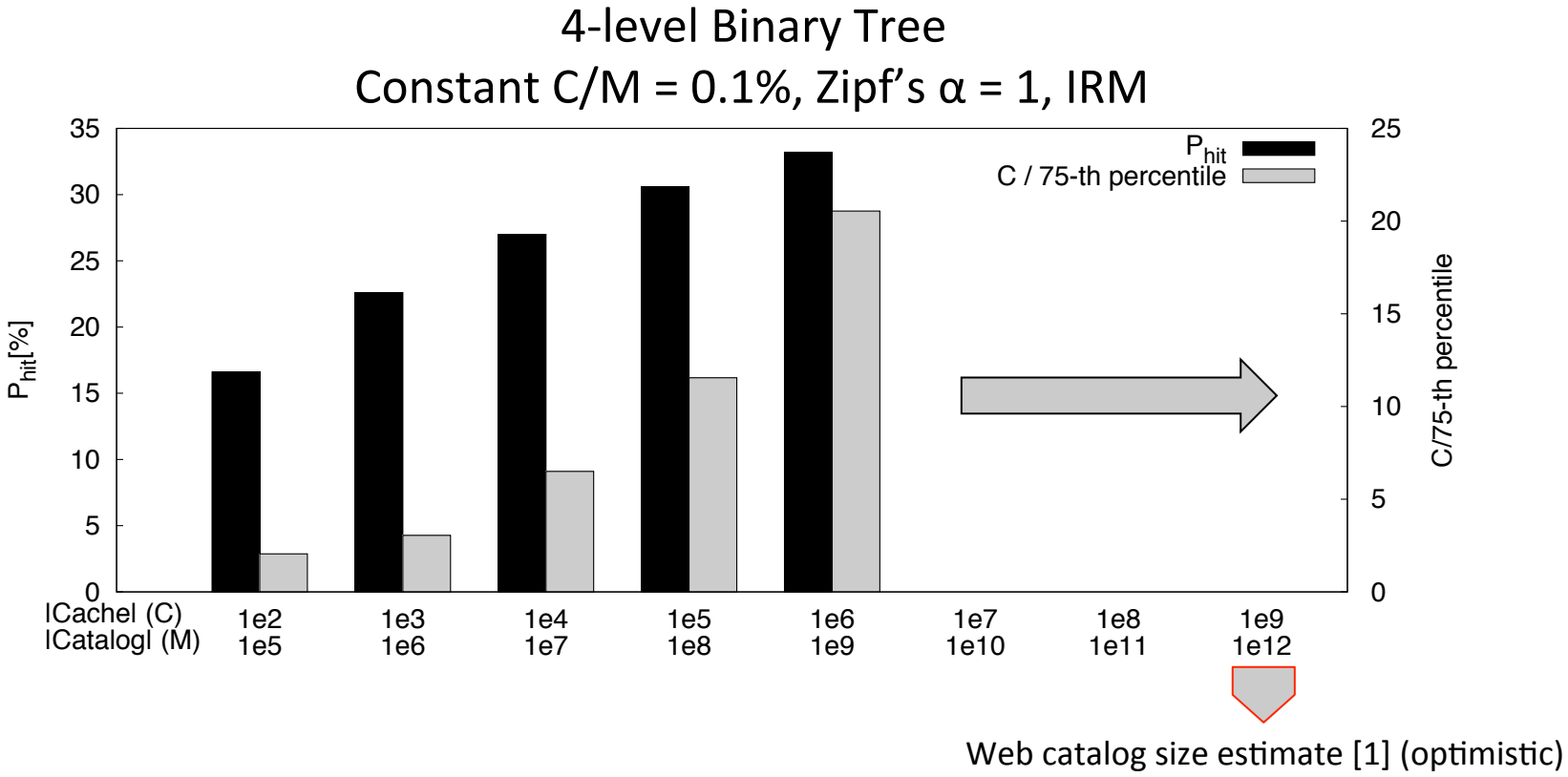
michele.tortelli@telecom-paristech.fr

MOTIVATION

Some phenomena only appear @ scale…

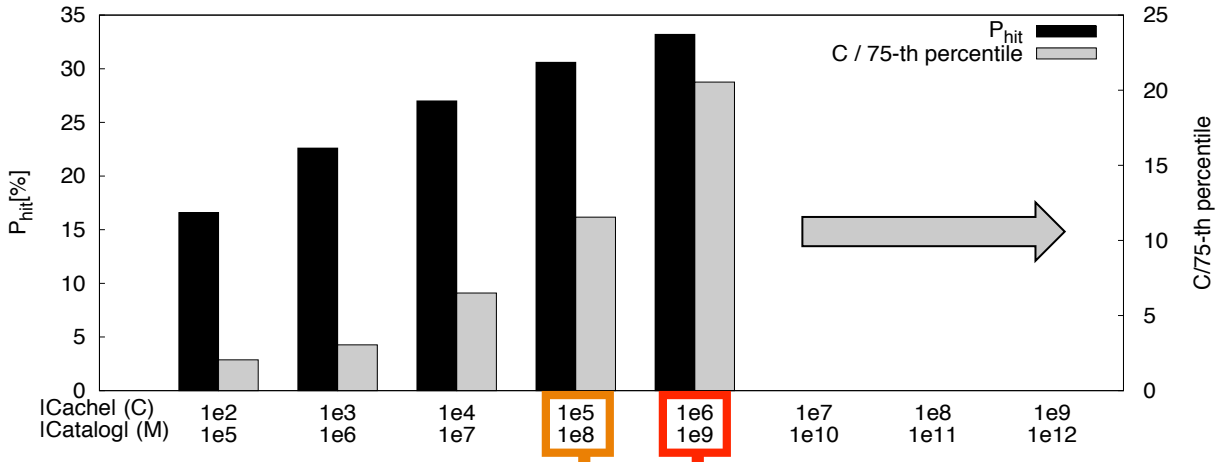


Some parameters should be fitted @ scale…

[1] K. Pentikousis et al., Information-centric networking: Evaluation methodology, Internet Draft - (Oct. 2015)

LIMITATIONS

People have limited CPU & Memory



CPU = 4089 s
Memory = 673 MB

CPU = 41084 s
Memory = 6.8 GB

(ccnSim v0.4-alpha)

One order of magnitude more becomes resource expensive

- Analytical Models → Tractability obtained at the expense of realism
  Require careful instrumentation
- Event-driven Simulation → Massive computing power at large scale
  Inefficient (wasting time and memory with expected events)

IDEA

Time to Live (TTL) caches +

Downscaling with factor Δ +

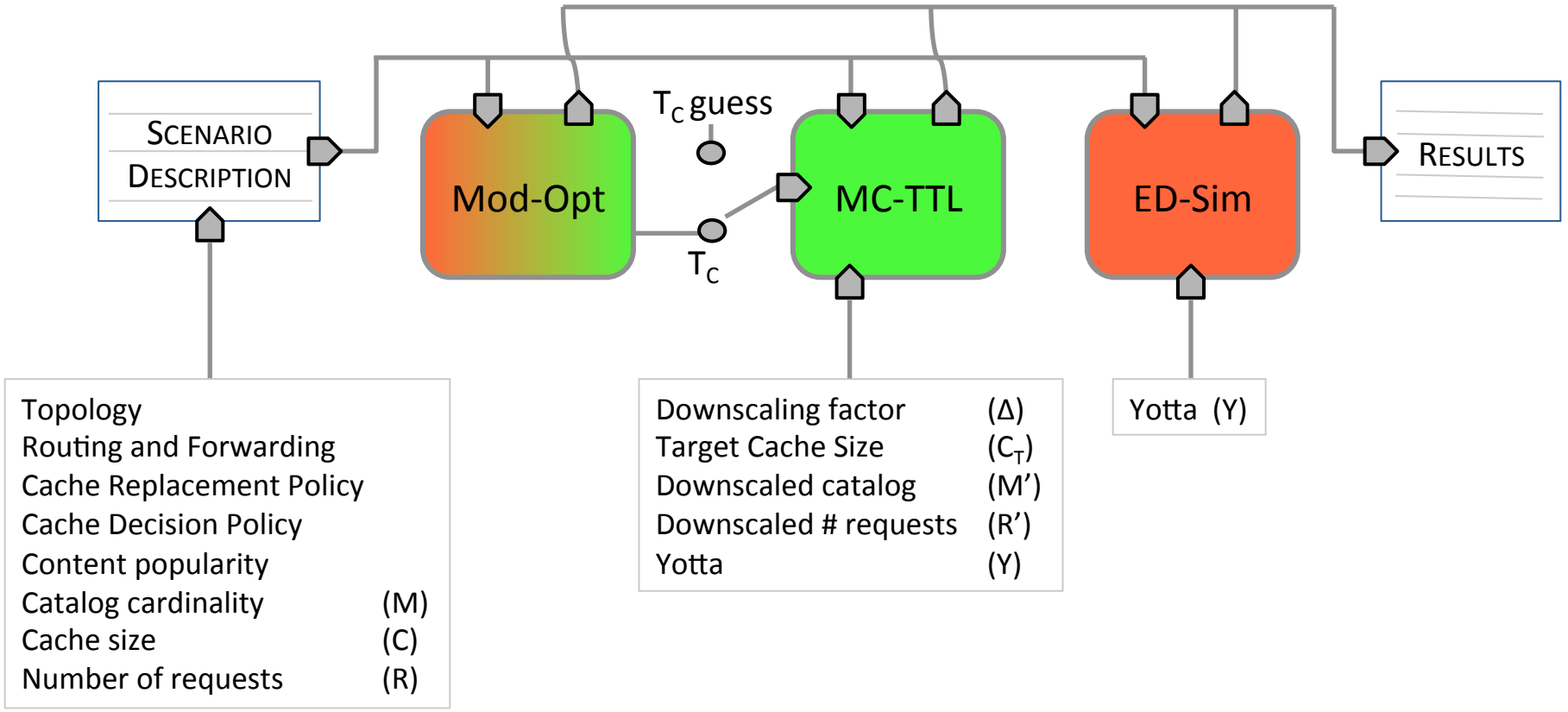
Rejection Inversion Sampling +

Error correction with feedback loop =

Downscaled MonteCarlo TTL-based (MC-TTL) Simulation

Ex: with Δ=1e5 → ~100x CPU & Memory reduction and ~2% Accuracy

UNDER THE HOOD



RESULTS I – VERY LARGE SCENARIO

4-level Binary Tree

M=1e9 - R=1e9 - C=1e6 - Δ=1e5 - C_T=10 - Y = 0.75

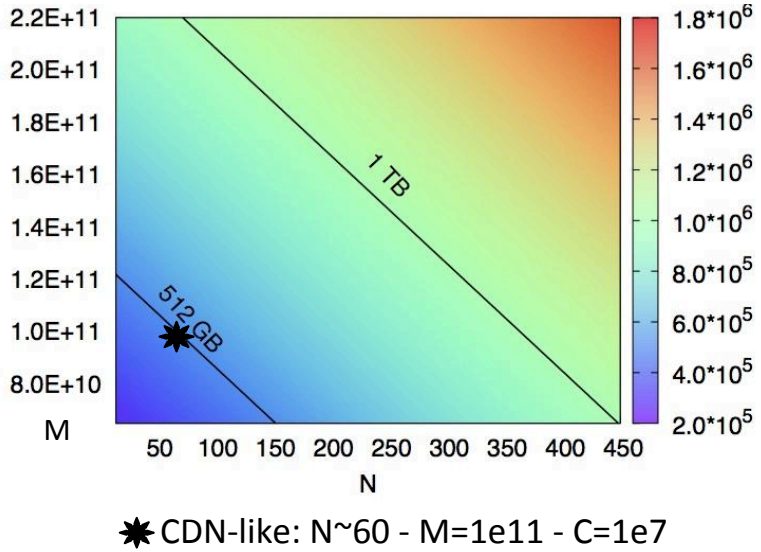
Cache Decision Policy		P_hit	CPU [s]	Gain	Mem [MB]	Gain
LCE	ED-Sim	33.2	41084	**160x**	6371	**168x**
	MC-TTL	31.4	256		38	
FIX0.1	ED-Sim	35.4	26232	**90x**	6404	**168x**
	MC-TTL	34.0	291		38	
2-LRU	ED-Sim	37.0	39031	**97x**	8894	**234x**
	MC-TTL	36.1	402		38	

RESULTS II – VERY² LARGE SCENARIO

Memory Model Fitting (ED-SIM)

$$Mem = (1.65 \cdot 10^{-4}) \cdot N \cdot C + 4 \cdot 10^{-6} \cdot M + 19.83 \quad [MB]$$

- 1 cache entry ≈ 165 Bytes
- 1 catalog entry = 4 Bytes
- Fix cost ≈ 19.83 MB



✸ CDN-like: N~60 - M=1e11 - C=1e7

With MC-TTL… You can!

	Scenario (**MC-TTL**)	Mem[MB]	CPU [s]	Cycles
4-level Binary Tree	M=1e10 - R=1e10 - C=1e6 - Δ=1e5 - C_T=10 - Y = 0.75	**45**	**1556**	1
	M=1e11 - R=1e11 - C=1e6 - Δ=1e5 - C_T=10 - Y = 0.75	**45.2**	**30600**	2
CDN-like (N=67)	M=1e11 - R=1e11 - C=1e6 - Δ=1e5 - C_T=10 - Y = 0.75	**106.5**	**16886**	1
	M=1e11 - R=1e11 - C=1e7 - Δ=1e6 - C_T=10 - Y = 0.75	**31**	**44953**	3

CONCLUSION

- Extreme scalability with a general methodology
  Implementable in every simulator (ndnSIM, Icarus, …)

- Available in ccnSim v0.4-alpha
  (http://perso.telecom-paristech.fr/~drossi/ccnSim)

- Technical Report (slightly old)
  M. Tortelli, D. Rossi and E. Leonardi,
  Model-Graft: Accurate, Scalable and Flexible Analysis of Cache Networks
  Tech. Rep. [CCN-TR15], Telecom ParisTech, 2015.

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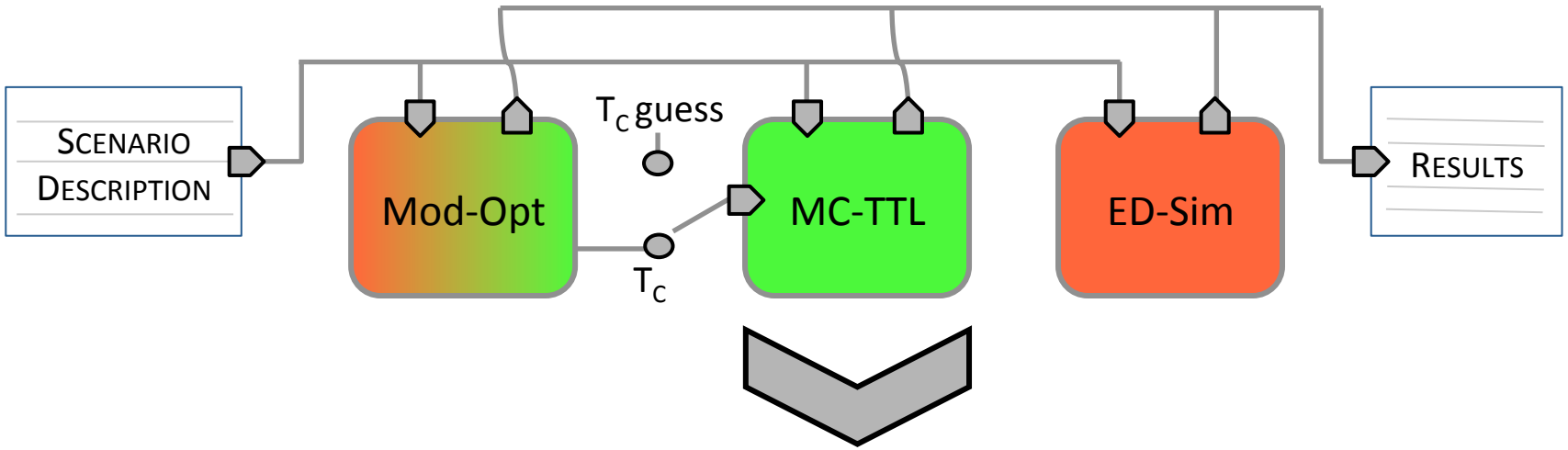
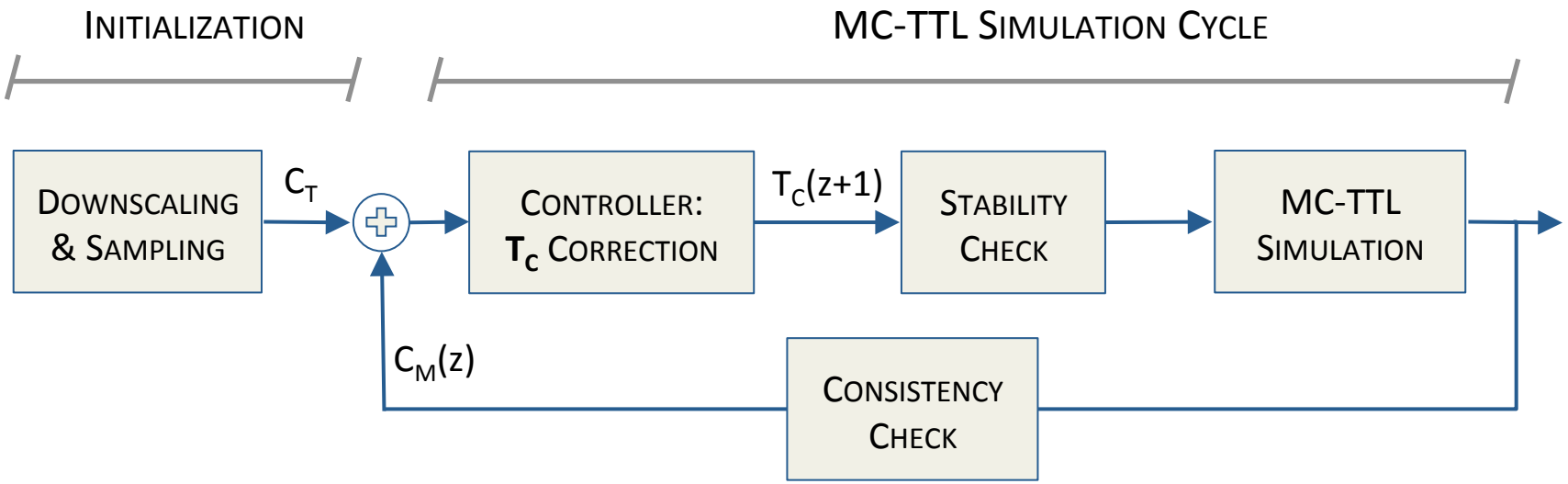
THANK YOU !

QUESTIONS ?

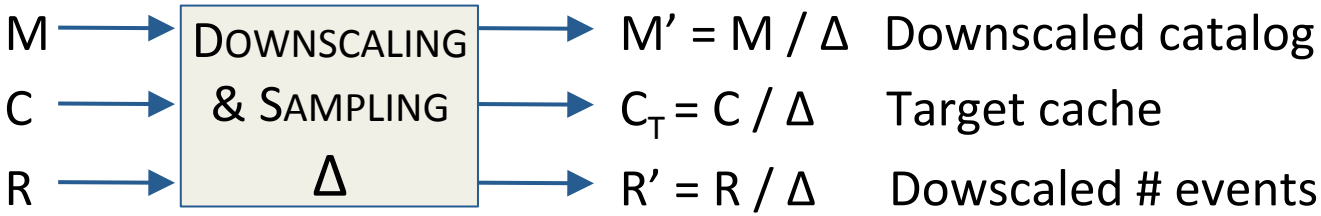
BACKUP SLIDES

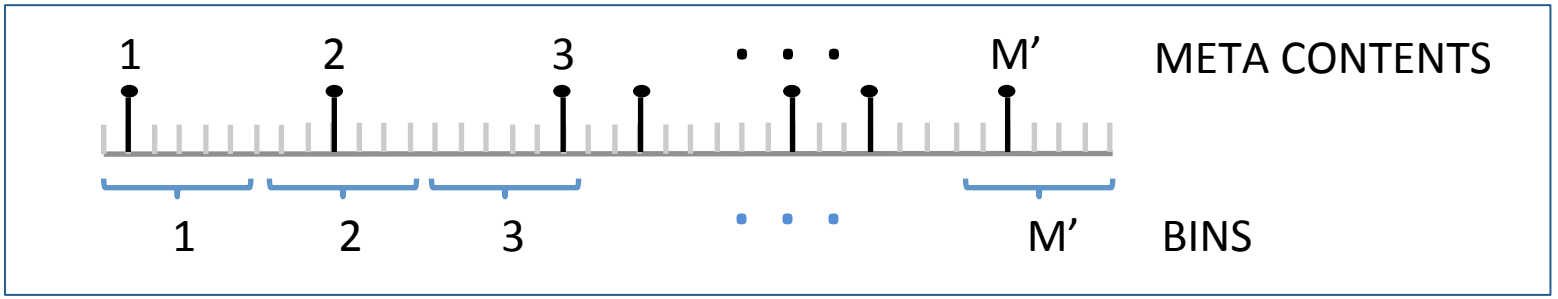
UNDER THE HOOD





DOWNSCALING & SAMPLING





Meta content n-th bin → $\mathcal{M}'_n$ Δ contents of the n-th bin

$t \in [(n-1)\Delta+1; n\Delta]$

Requested with probability $p \propto \lambda_t / \sum_{j \in \mathcal{M}'_n} \lambda_j$

→ NOT SCALABLE!
M' • O(Δ) init cost
M' • O(Δ) space cost
O(logΔ) sampling time

Rejection Inversion Sampling (VERY SCALABLE!)

Extract Zipf's distributed random numbers between [1, Δ]
No Memory and O(1) runtime complexity

STABILITY CHECK

Pivotal role to simulate the R'(1) requests at steady state

Dynamic transient period
(routing, meta-caching, topology,…) → **Adaptive Stability Monitor**

- Coefficient of Variation (CV) of the mean hit probability (CV = std(p_{hit}) / E(p_{hit}))
- Batch mean of W samples (new sample iif active cache and state change)
- Check stability (i.e., CV < $5 \cdot 10^{-3}$) for the first N' = Y•N nodes, where Y ∈]0,1].

(1)

ED-Sim: end = R / (Λ*Cl), with $\Lambda = \sum_{i \in M} \lambda_i$

MC-TTL: end' = R' / (Λ'*Cl), with $\Lambda' = \sum_{j \in M'} \lambda_i \approx \Lambda / \Delta$

Since end = end' → R' = R / Δ

T_C Correction & Consistency Check

Hp: each TTL cache will store, on average, $\mathbf{C_T = C/\Delta}$ contents at steady state if its *eviction time* corresponds to the *characteristic time* T_C of its equivalent LRU non-scaled cache.

Controlled Variable = Measured Cache Size $\mathbf{C_M}$

$$C_{Mi}(k+1) = \frac{C_{Mi}(k)\ t(k) + B_i(k+1)\ [t(k+1) - t(k)]}{t(k+1)}$$

$C_{Mi}(k+1)$ = online avg of the cache size of the i-th node @ k-th measurement time

$B_i(k+1)$ = actual # contents stored inside the TTL cache

Samples are taken every miss event with probability p=0.1

Consistency Check (after R' events)

$$\frac{1}{N'} \sum_{i \in N'} \frac{|C_T - C_{Mi}|}{C_T} < 0.1$$

Same N' nodes
(coherent with stability check)

YES → End MC-TTL simulation

NO → Correct Tc and start new MC-TTL cycle

$$T_{Ci}(z+1) = T_{Ci}(z)\ \left(\frac{C_T}{C_{Mi}(z)}\right)$$

C_M distance from C_T connected to input T_C
distance from real T_C (the higher T_C the bigger C_M)

T_C Sensitivity - I

4-level Binary Tree

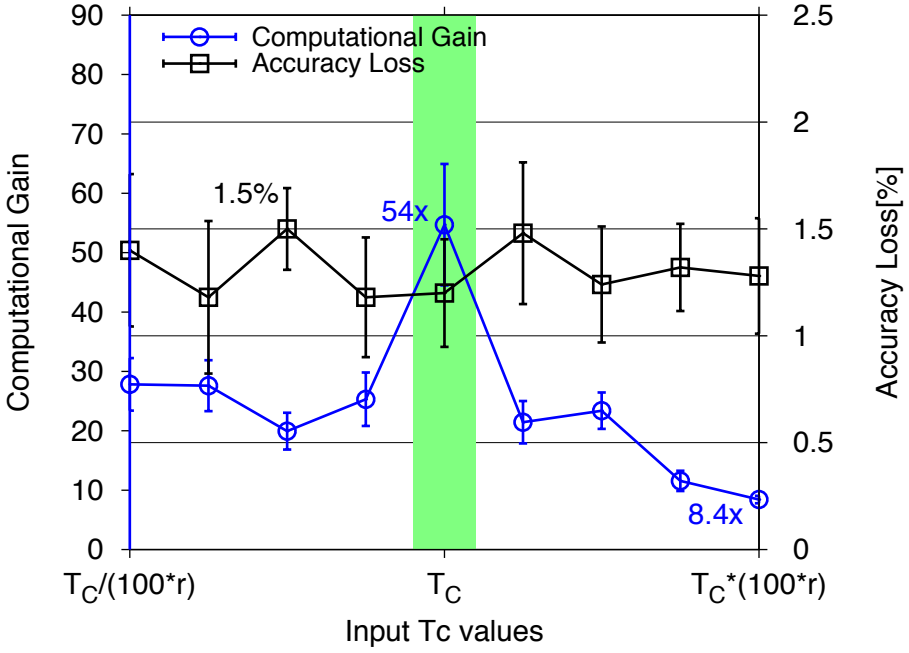
M=1e6 - R=1e7 - C=1e3 - Δ=1e2 - C_T=10 - Y = 1

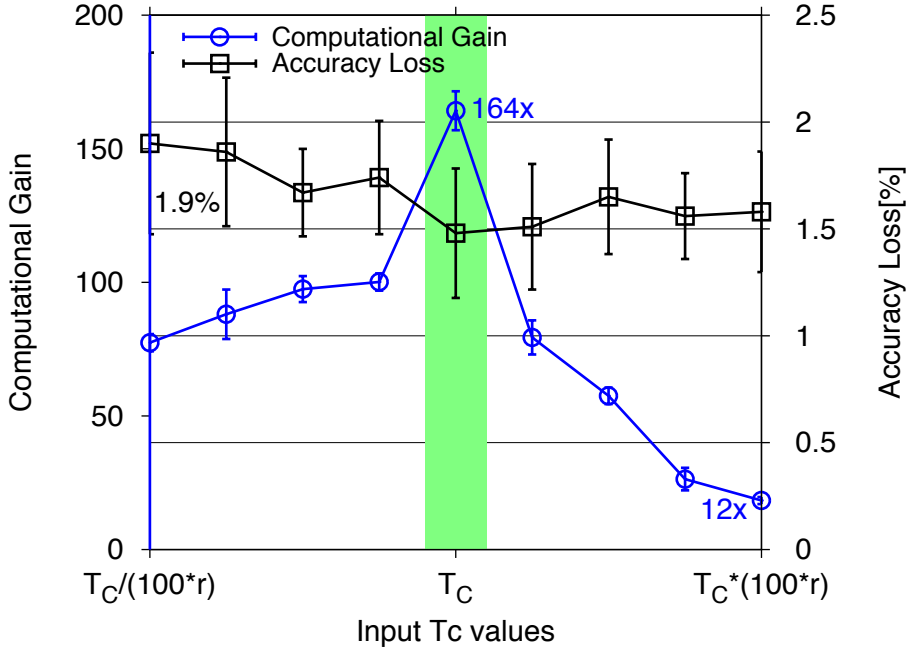
	Tc Values [s]			
Level	**LCE**	**FIX0.1**	**LCD**	**2-LRU (Name/Main)**
0 (Root)	11	115	13	14 / 654
1	22	218	1090	27 / 1040
2	43	400	1250	51 / 1420
3 (Leaves)	75	570	815	75 / 1255
P_hit @ Stab.	22.8	25.9	28.5	29.2
P_hit @ End.	22.8	26.3	28.1	29.4
Stab. Time	8.4	10.3	14.4	23.7
End Time	482.7	390	386	456.3

T_C Sensitivity - II

4-level Binary Tree

M=1e8 - R=1e8 - C=1e5 - Δ=1e4 - C_T=10 - Y = 0.75





LCD

ED-Sim: Phit = 34.5% - CPU = 2801 s - Mem = 660 MB

Mod-Opt: Phit = --% - CPU = -- s - Mem = -- MB

MC-TTL: - Mem ≈ 38 MB (18x)

LCE

Phit = 30.6% - CPU = 4089 s - Mem = 673 MB

Phit = 29.8% - CPU = 740 s - Mem = 24240 MB

- Mem ≈ 38 MB (18x)

YOTTA SENSITIVITY

NDN Testbed

M=1e6 - R=1e7 - C=1e3 - Δ=1e3 - C_T=10 - MC = 2-LRU

Sim. Type	Yotta	P_hit @ Stab.	P_hit @ End	Stab. Time [s]	End Time [s]
ED-Sim	1	33.8	33.9	99.7	458.0
	0.95	33.7	33.9	42.4	432.5
	0.9	33.7	33.9	35.0	421.9
	0.75	33.6	33.9	29.3	408.13
	0.5	32.8	33.9	15.4	401.33