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DYNAMIC LINK NETWORKS:

EMULATION AND VALIDATION

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DYNAMIC LINK NETWORKS

- Dynamic link network - a computer network where each link has a set of parameters that may change (e.g., bandwidth, delay, ...)
- Let's consider N = (V , E, p1 (e), p2 (e)) where:

$$V = \{1,2,3,4\}$$

$$E = \{(1,2),(2,1),(1,3),(3,1),(1,4),(4,1),(2,4),(4,2),(3,4),(4,3)\}$$

$$p_1(e) = b((s,d)) = \begin{cases} \{4,5,6\}, & \text{if } d = 2 \\ \{2,3,4\}, & \text{otherwise} \end{cases}$$

$$p_2(e) = d((s,d)) = \begin{cases} \{1,2\}, & \text{if } d = 2 \\ \{9,10\}, & \text{otherwise} \end{cases}$$

- **How to reduce the gap between real world and simulation/emulation environments ?**
- **How adequate are simulators/emulators ?**

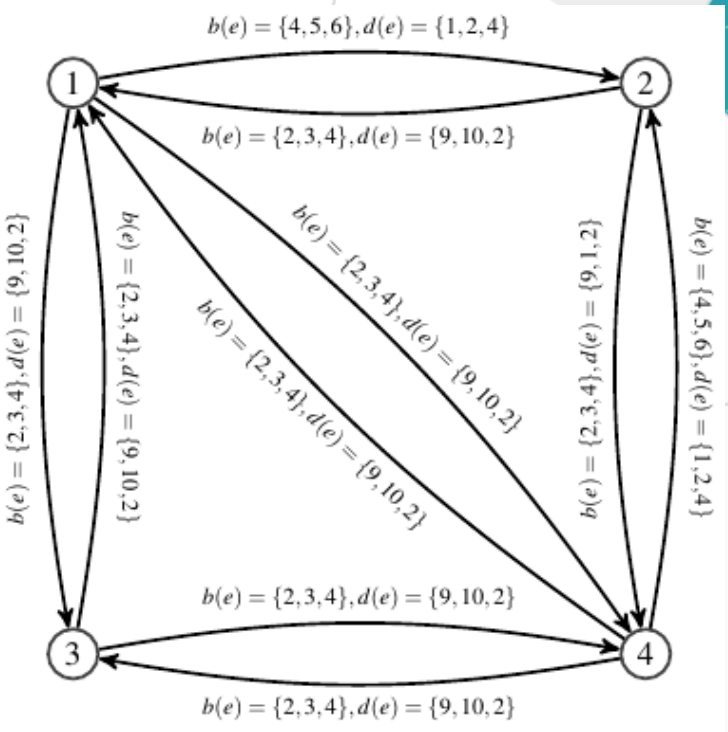

Fig.1. Example Dynamic Link network

EMULATION

- An emulator platform for Dynamic Link networks has been developed [1]
  - Flexible (executes any existing software)
  - Dynamic change the links' parameter values
  - Execute traffic scenarios by a timed sequence of network packets

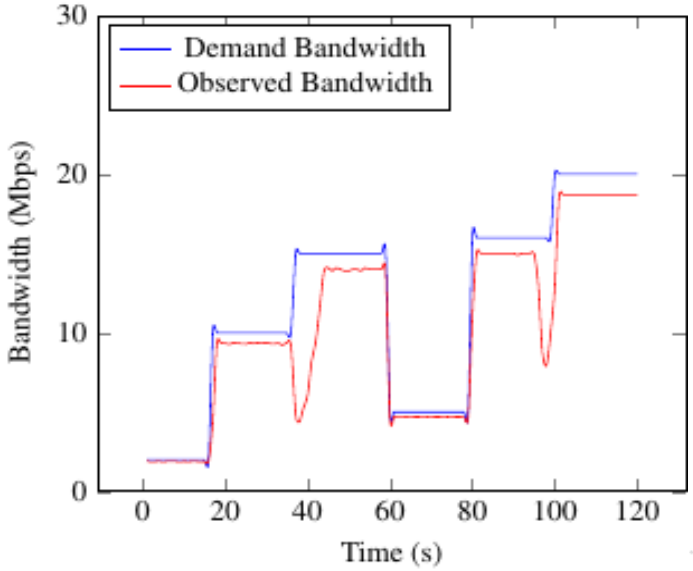

Fig.2.Varying emulated bandwidth by demand (network in Fig.1)

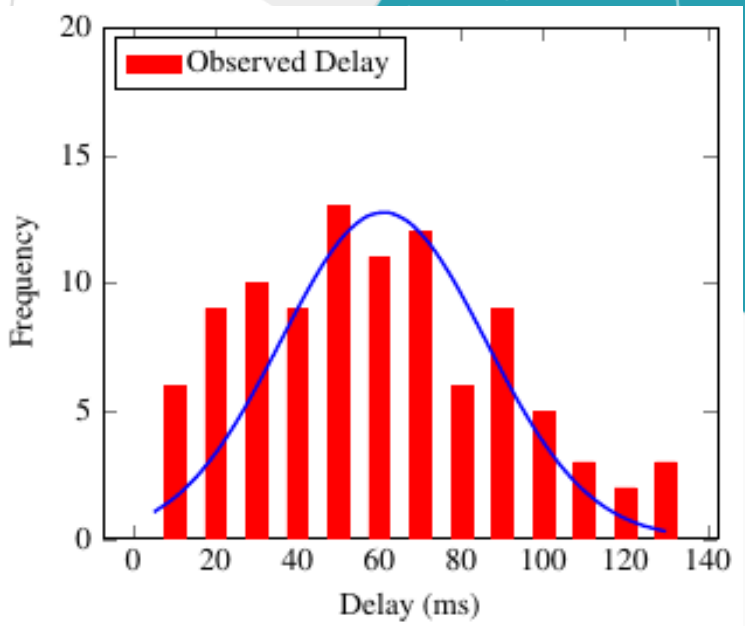

Fig.3. Emulated delay histogram (network in Fig.1)

[1] E.Petersen, J.Lopez, N.Kushik, C.Poletti and D.Zenghlache,"Dynamic Link Network Emulation: A Model-based Design", 2022 The 17th International Conference on Evaluation of Novel Approaches to Software Engineering (ENASE), 2022, pp. 536-543, ISBN: 978-989-758-568-5, ISSN: 2184-4895

VALIDATION

- A formal verification approach using MSFOL has been proposed [3]. The network model w.r.t. various network properties can be verified.
  - - Model validation
  - - Run-time verification of the emulator

Description	Formula
The links are symmetric (for any link a return link exists)	$\pi_{\leftrightarrows} = \forall x : \mathbb{Z}\ (((x \geq 1) \wedge (x \leq \lvert E \rvert)) \implies \exists y : \mathbb{Z}\ ((y \geq 1) \wedge (y \leq \lvert E \rvert) \wedge (src(E[x]) = dst(E[y])) \wedge (dst(E[x]) = src(E[y]))))$
The edges in the edge array are composed of nodes in the node array	$\pi_{eV} = \forall i : \mathbb{Z}\ (((i \geq 1) \wedge (i \leq \lvert E \rvert)) \implies (\exists j,k : \mathbb{Z}\ ((src(E[i]) = V[j]) \wedge (dst(E[i]) = V[k]))))$
The delay of all links is always less or equal to the constant D	$\pi_D = \forall i : \mathbb{Z}\ (((i \geq 1) \wedge (i \leq \lvert E \rvert)) \implies (d(E[i]) \leq D))$
The bandwidth of all links is greater or equal to the threshold B	$\pi_B = \forall i : \mathbb{Z}\ (((i \geq 1) \wedge (i \leq \lvert E \rvert)) \implies (b(E[i]) \geq B))$
The network topology density is at least δ	$\pi_\delta = (\lvert E \rvert / (\lvert V \rvert * (\lvert V \rvert - 1))) \geq \delta$

Table 1. Network properties of interest

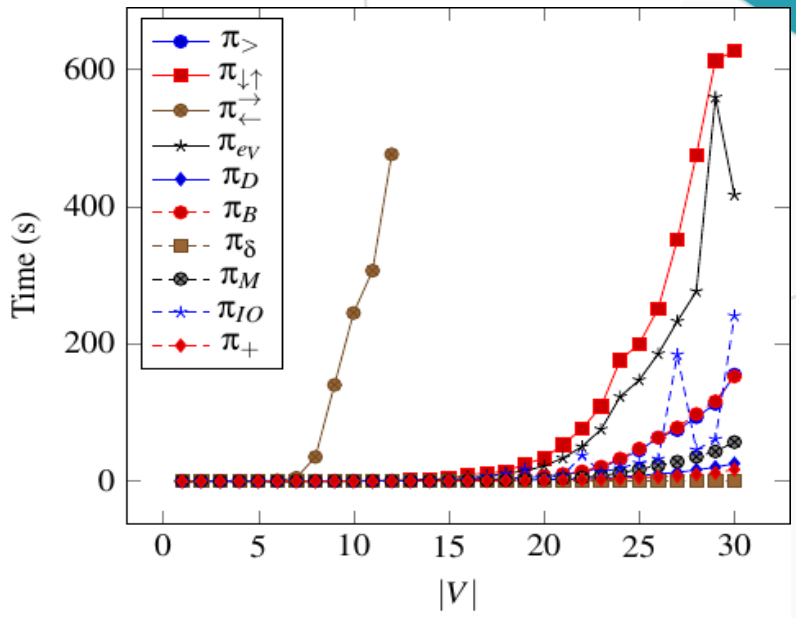

Fig.6. Time evaluation of emulator verification

[3] E.Petersen, J.Lopez, N.Kushik, C.Poletti and D.Zenghlache,"On using SMT-Solvers for Modeling and Verifying Dynamic Network Emulators: (Work in Progress)", 2020 IEEE 19th International Symposium on Network Computing and Applications (NCA), 2020, pp. 1-3, Doi: 10.1109/NCA51143.2020.9306731

SIMULATION

- A Cellular Automaton has been proposed to simulate and test different network evolution patterns [2]

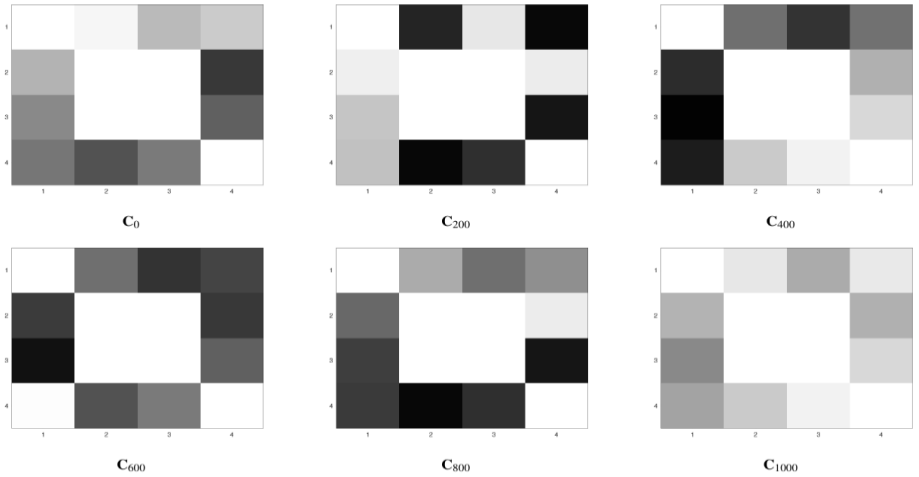

Fig.4. CA evolution for a random initial configuration (network in Fig.1)

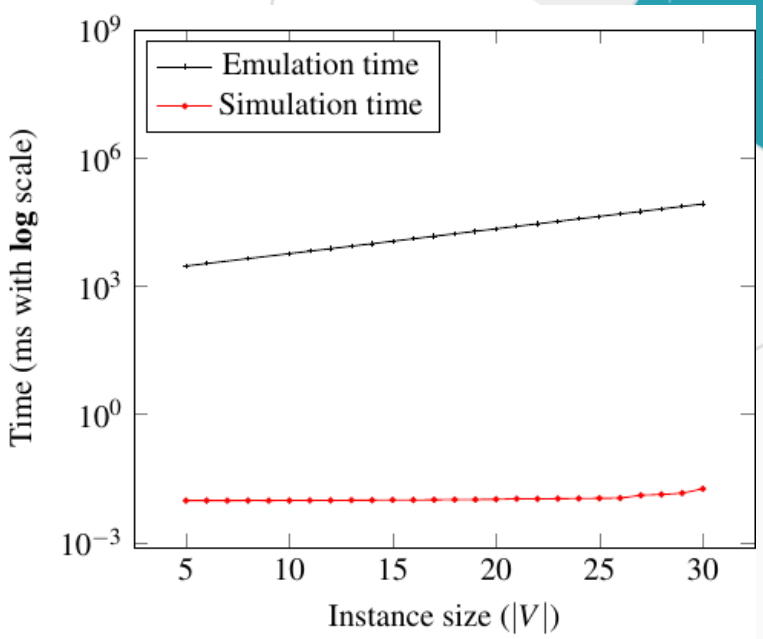

Fig.5. Simulation vs emulation performance

[2] E.Petersen, J.Lopez, N.Kushik, C.Poletti and D.Zenghlache,"On using Cellular Automata for Modeling the Evolution of Dynamic-Link Network Parameters", 2022 IEEE 21st International Symposium on Network Computing and Applications (NCA), 2022, Vol. 21 pp. 297-301, Doi: 10.1109/NCA57778.2022.10013557

THANK YOU !,

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