DYNAMIC LINK NETWORKS:

EMULATION AND VALIDATION

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MOTIVATION

- Growing demand for interactive services, multimedia and network capabilities in modern networks
- Evaluation and Validation are critical for newly provided solutions
- Dynamic link networks, i.e., networks whose links parameters change, complicate the emulation environment
  - How to reduce the gap between real world and simulation/emulation environments ?
  - How adequate are simulators/emulators ?

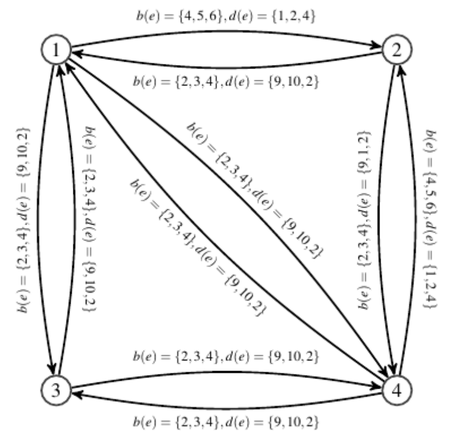

Fig. 1. Example Dynamic Link network

EMULATION

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

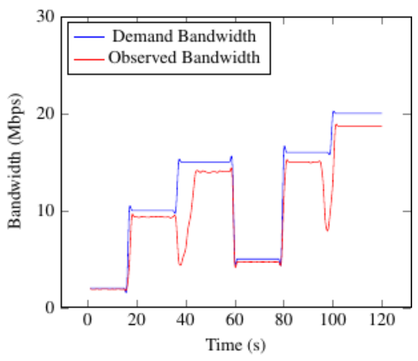

Fig.2. Varying emulated link bandwidth by demand (network in Fig.1)

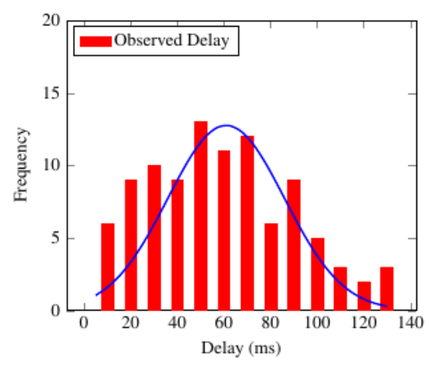

Fig.3. Emulated link delay histogram (network in Fig.1)

- A Cellular Automaton has been proposed to simulate and test different network evolution patterns [3]

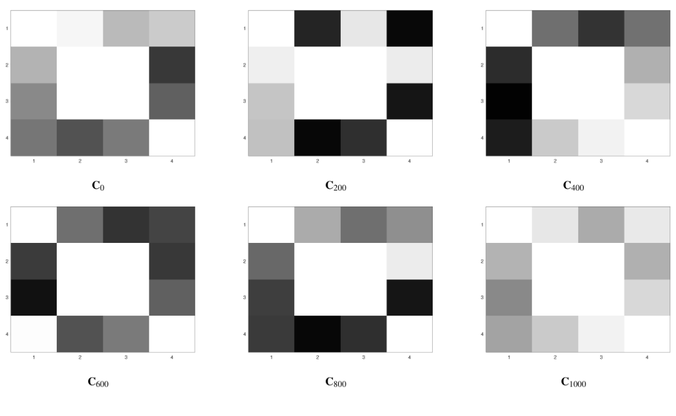

Fig.4. CA evolution for a random initial configuration (network in Fig.1)

VALIDATION

- A formal verification approach using MSFOL has been proposed [2]
  - 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

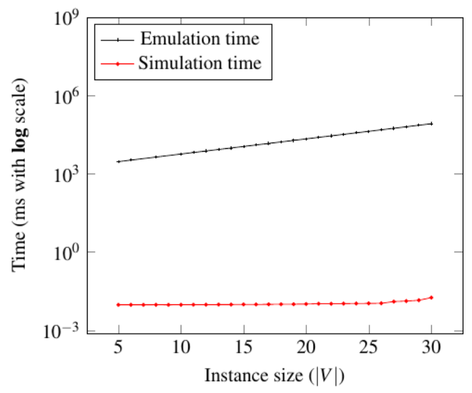

Fig.5. Simulation vs emulation performance

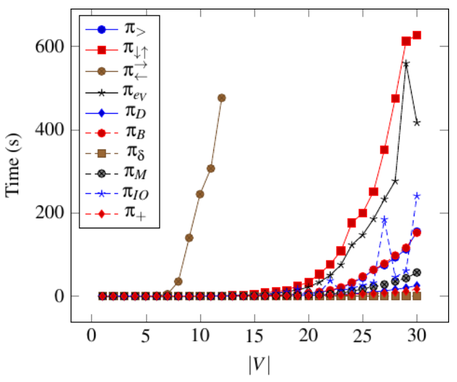

Fig.6. Time evaluation of emulator verification

CONCLUSION

- A hybrid platform (emulation and simulation) with pattern generation capabilities for dynamic link networks has been presented

FUTURE WORK

- Traffic generation and related test generation strategies
  - Learning strategies and stochastic properties are to be integrated

REFERENCES

1. E.Petersen, J.Lopez, N.Kushik, C.Poletti and D.Zeghlache,"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
2. E.Petersen, J.Lopez, N.Kushik, C.Poletti and D.Zeghlache,"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
3. E.Petersen, J.Lopez, N.Kushik, C.Poletti and D.Zeghlache,"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

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