

WSIZ, 2023

Verification of protocols by Petri nets

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Modeling by Petri and Sleptsov nets

- Verification of protocols by Petri nets
- Model analysis methods. Composition of clans
- Analysis of Computational Grids and Clouds by Infinite Petri Nets
- Evaluation of System Performance by Colored Petri Nets
- Computing on Sleptsov networks

Protocol

- **Set of systems' interaction rules**
- **and formats of information used**

Examples of protocols

- **Telecommunications (networking) – TCP/IP**
- **Diplomatic, law**
- **Organization of manufacturing processes**

Deadlock

- **Mutual blocking of processes (which share resources)**
- **Infinite waiting – «hanging»**
- **There are enough amount of resources for well-coordinated joint functioning of processes**
- **It is required to modify, «improve» protocol**

Example of deadlock



Worker 1



hammer



chisel



Worker 2

Protocols of workers

Worker 1:

- Take hammer
- Take chisel
- Gouge a hole
- Put chisel
- Put hammer

Worker 2:

- Take chisel
- Take hammer
- Gauge a hole
- Put hammer
- Put chisel

Deadlock

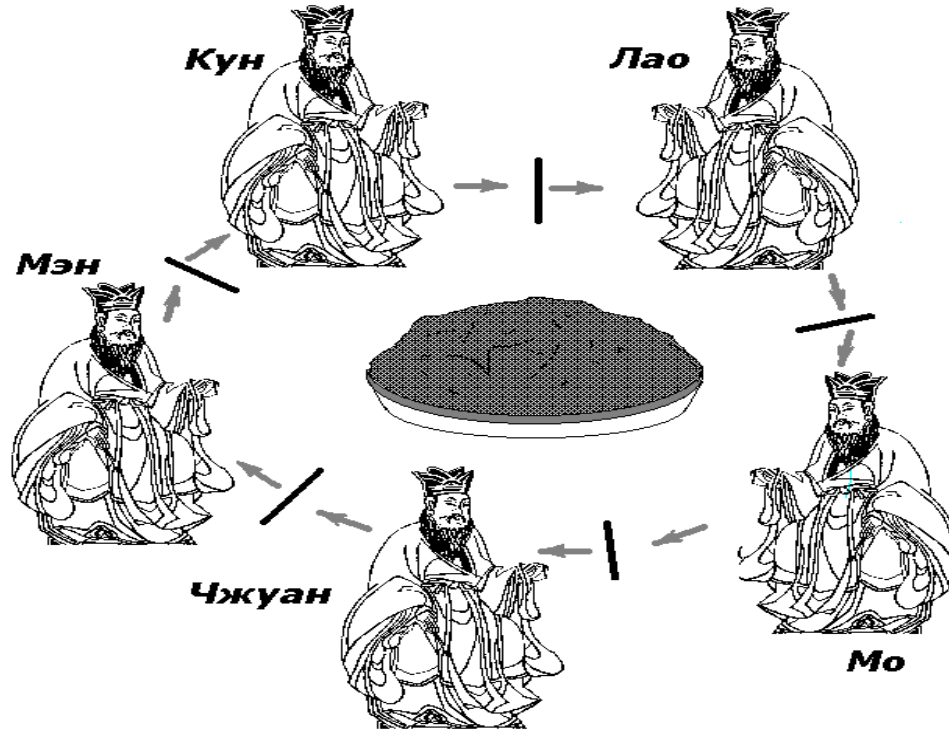


Worker 1 took hummer



Worker 2 took chisel

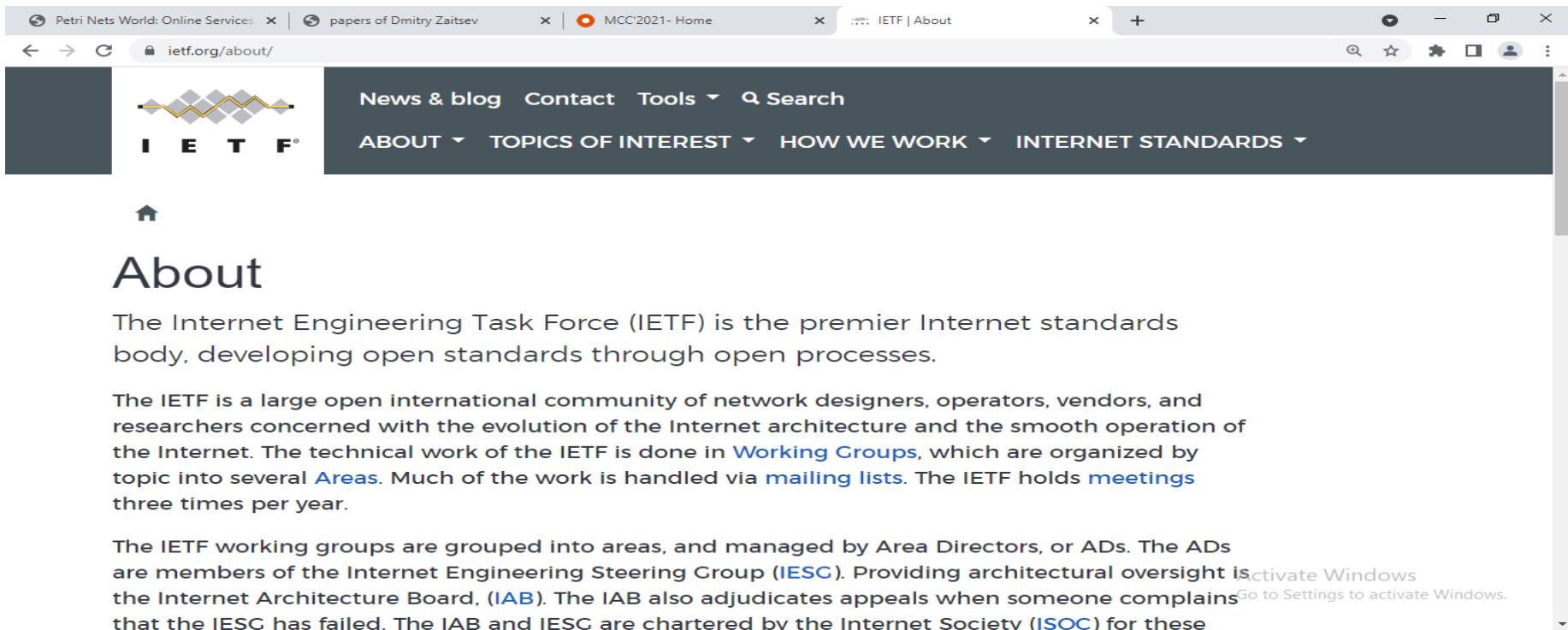
Task about dining philosophers



Standards of networking protocols

- The Internet Engineering Task Force (IETF) – <http://ietf.org>
- Institute of Electrical and Electronics Engineers (IEEE) – <http://ieee.org>
- International Telecommunication Union (ITU) – <http://itu.int>
- International Organization for Standardization (ISO) – <http://iso.org>

IETF – References for Comments (RFC)



The screenshot shows a web browser with multiple tabs open. The active tab is 'IETF | About'. The address bar shows 'ietf.org/about/'. The website header includes the IETF logo (a stylized diamond pattern) and navigation links: 'News & blog', 'Contact', 'Tools', 'Search', 'ABOUT', 'TOPICS OF INTEREST', 'HOW WE WORK', and 'INTERNET STANDARDS'. The main content area is titled 'About' and contains the following text:

The Internet Engineering Task Force (IETF) is the premier Internet standards body, developing open standards through open processes.

The IETF is a large open international community of network designers, operators, vendors, and researchers concerned with the evolution of the Internet architecture and the smooth operation of the Internet. The technical work of the IETF is done in [Working Groups](#), which are organized by topic into several [Areas](#). Much of the work is handled via [mailing lists](#). The IETF holds [meetings](#) three times per year.

The IETF working groups are grouped into areas, and managed by Area Directors, or ADs. The ADs are members of the Internet Engineering Steering Group ([IESG](#)). Providing architectural oversight is the Internet Architecture Board, ([IAB](#)). The IAB also adjudicates appeals when someone complains that the IESG has failed. The IAB and IESG are chartered by the Internet Society ([ISOC](#)) for these

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RFC793 – TRANSMISSION CONTROL PROTOCOL

(<https://www.rfc-editor.org/pdf/rfc793.txt.pdf>)

September 1981

Transmission Control Protocol

Page 7

2. PHILOSOPHY

2.1. Elements of the Internetwork System

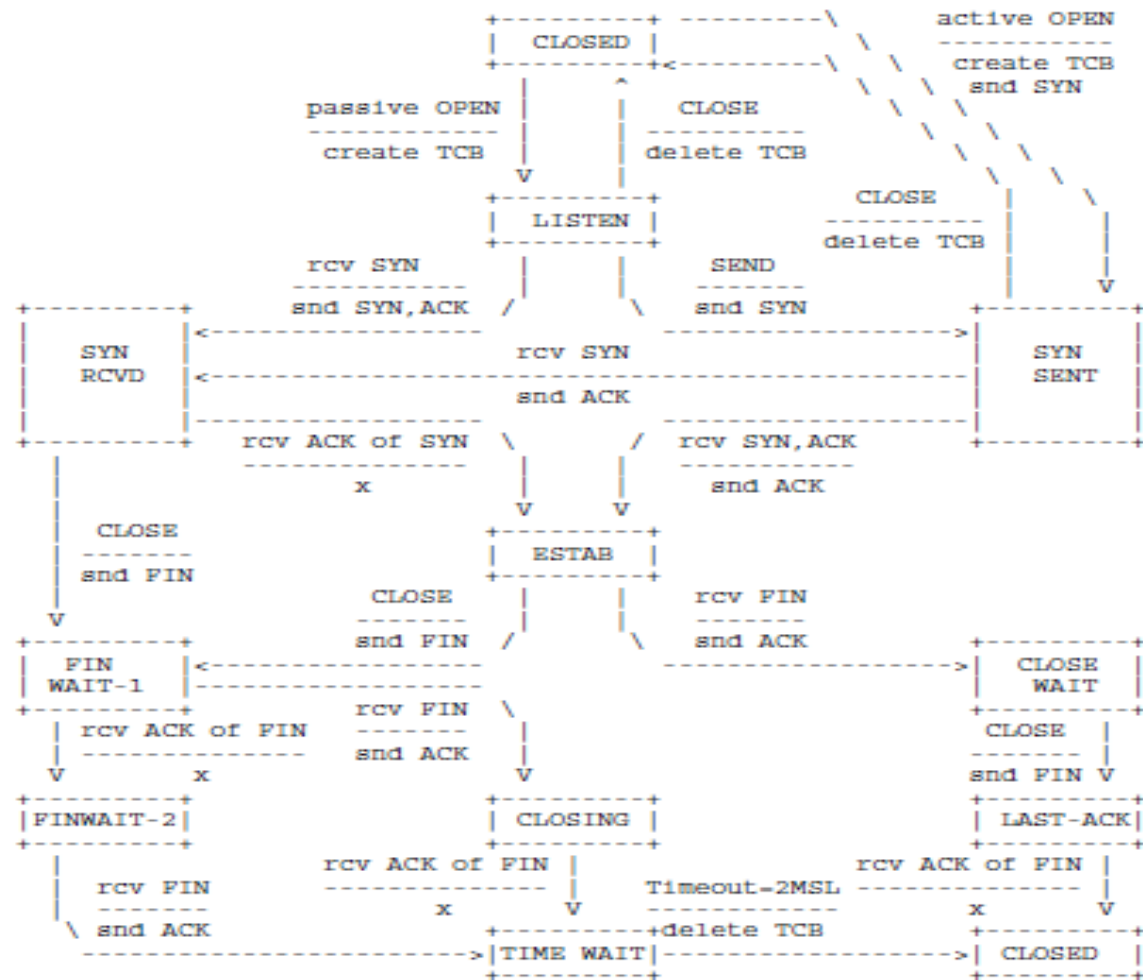
The internetwork environment consists of hosts connected to networks which are in turn interconnected via gateways. It is assumed here that the networks may be either local networks (e.g., the ETHERNET) or large networks (e.g., the ARPANET), but in any case are based on packet switching technology. The active agents that produce and consume messages are processes. Various levels of protocols in the networks, the gateways, and the hosts support an interprocess communication system that provides two-way data flow on logical connections between process ports.

The term packet is used generically here to mean the data of one transaction between a host and its network. The format of data blocks exchanged within the a network will generally not be of concern to us.

Hosts are computers attached to a network, and from the communication network's point of view, are the sources and destinations of packets. Processes are viewed as the active elements in host computers (in accordance with the fairly common definition of a process as a program in execution). Even terminals and files or other I/O devices are viewed as communicating with each other through the use of processes. Thus, all communication is viewed as inter-process communication.

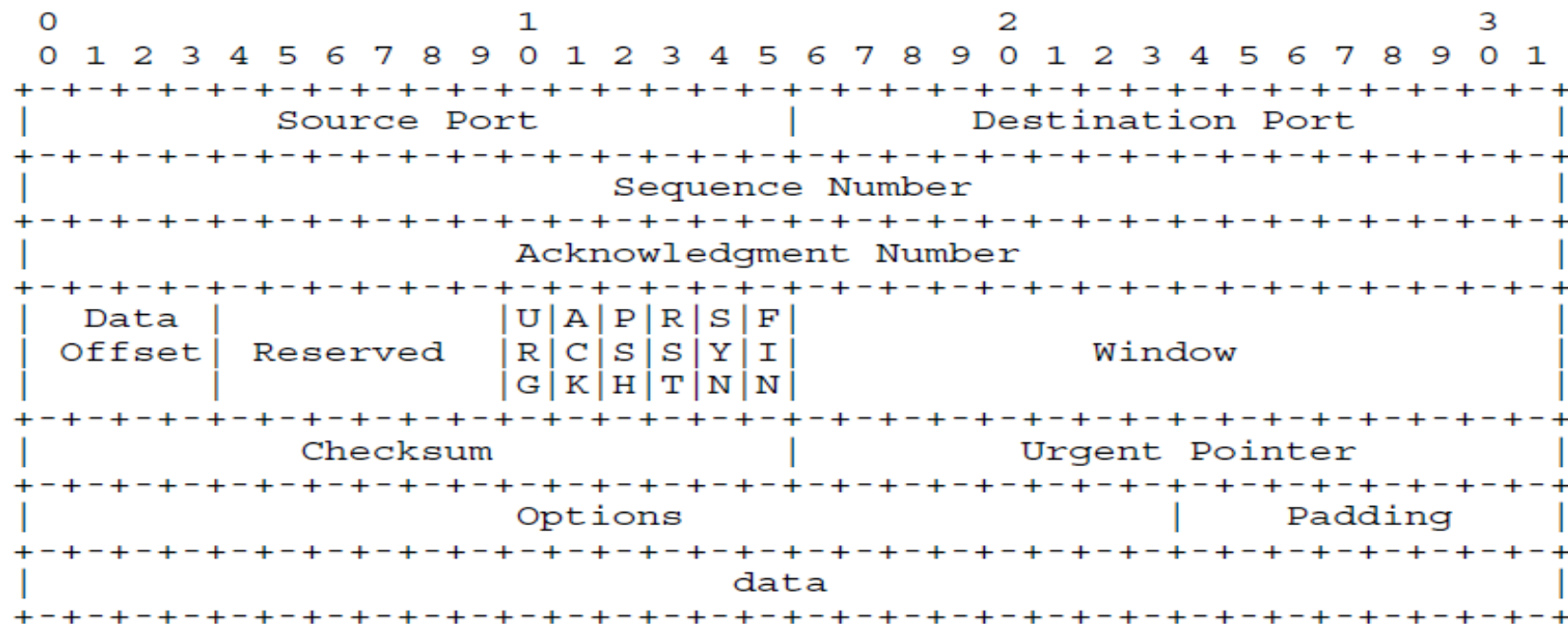
Since a process may need to distinguish among several communication streams between itself and another process (or processes), we imagine that each process may have a number of ports through which it communicates with the ports of other processes.

RFC793 – TCP Connection State Diagram



TCP Connection State Diagram

RFC793 – TCP Header Format

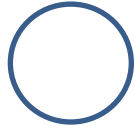


TCP Header Format

Petri net

- **Bipartite directed graph,**
- **on which a dynamic process is introduced.**
- **Parts of vertices:**
 - **Place – condition (circle)**
 - **Transition – event (rectangle)**
 - **Token – dynamic element (a dot inside place)**
- **Carl Petri, 1962**

Elements of Petri net



place



transition



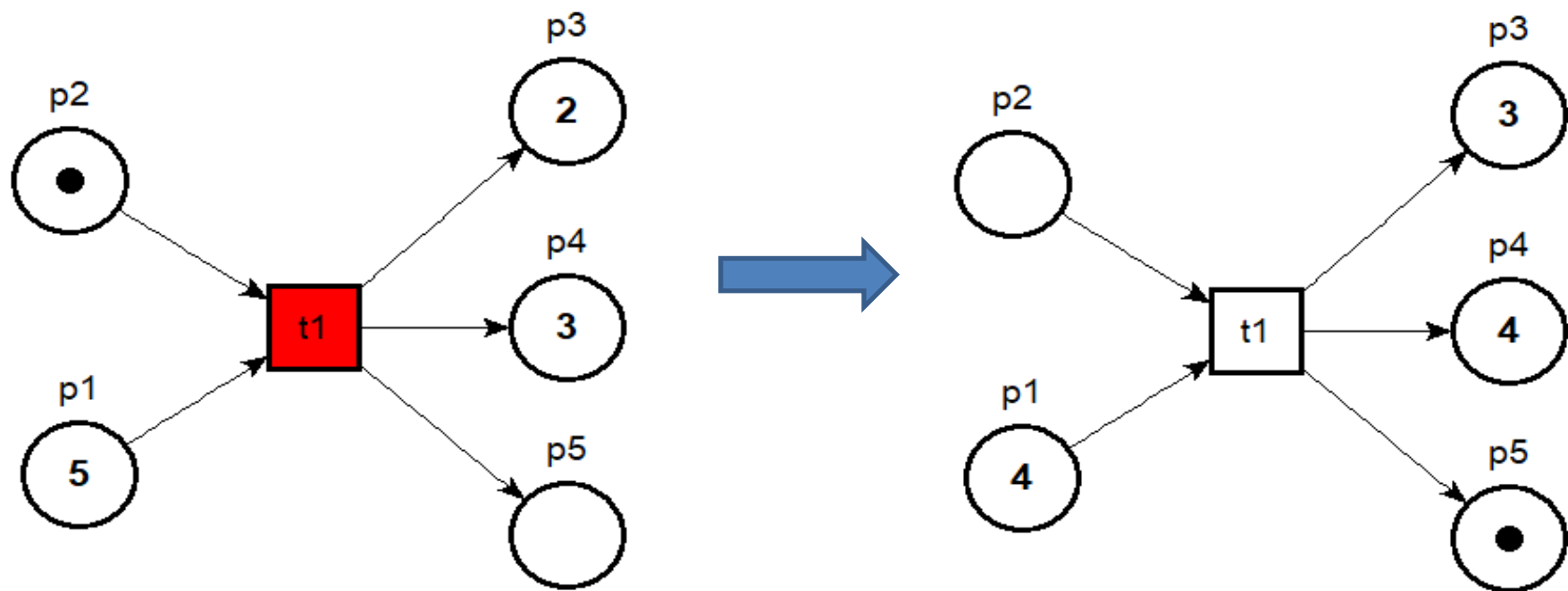
arc



token

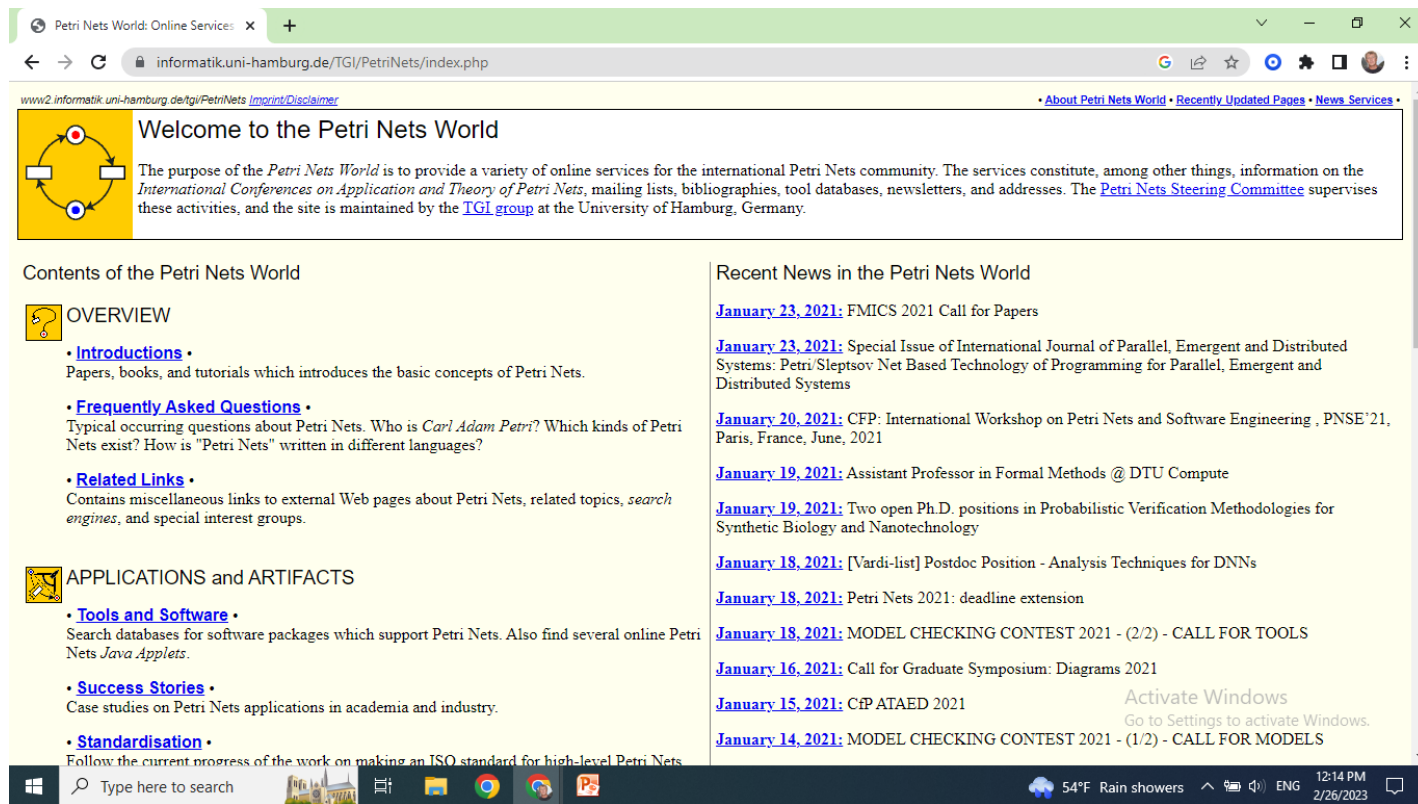


Firing a transition



Petri Nets World –

<https://www.informatik.uni-hamburg.de/TGI/PetriNets/>



The screenshot shows a web browser window displaying the Petri Nets World website. The browser's address bar shows the URL <https://www.informatik.uni-hamburg.de/TGI/PetriNets/index.php>. The website has a yellow header with a logo on the left and navigation links on the right. The main content area is divided into two columns. The left column contains sections for 'Contents of the Petri Nets World' and 'OVERVIEW', which lists 'Introductions', 'Frequently Asked Questions', and 'Related Links'. The right column contains 'Recent News in the Petri Nets World' with a list of recent events and announcements. At the bottom, there is a Windows taskbar with various icons and a system clock showing 12:14 PM on 2/26/2023.

Petri Nets World: Online Services

[informatik.uni-hamburg.de/TGI/PetriNets/index.php](#)

[www2.informatik.uni-hamburg.de/tgi/PetriNets](#) [Imprint/Disclaimer](#) [About Petri Nets World](#) [Recently Updated Pages](#) [News Services](#)

Welcome to the Petri Nets World

The purpose of the *Petri Nets World* is to provide a variety of online services for the international Petri Nets community. The services constitute, among other things, information on the *International Conferences on Application and Theory of Petri Nets*, mailing lists, bibliographies, tool databases, newsletters, and addresses. The [Petri Nets Steering Committee](#) supervises these activities, and the site is maintained by the [TGI group](#) at the University of Hamburg, Germany.

Contents of the Petri Nets World

OVERVIEW

- Introductions**
Papers, books, and tutorials which introduces the basic concepts of Petri Nets.
- Frequently Asked Questions**
Typical occurring questions about Petri Nets. Who is *Carl Adam Petri*? Which kinds of Petri Nets exist? How is "Petri Nets" written in different languages?
- Related Links**
Contains miscellaneous links to external Web pages about Petri Nets, related topics, *search engines*, and special interest groups.

APPLICATIONS and ARTIFACTS

- Tools and Software**
Search databases for software packages which support Petri Nets. Also find several online Petri Nets *Java Applets*.
- Success Stories**
Case studies on Petri Nets applications in academia and industry.
- Standardisation**
Follow the current progress of the work on making an ISO standard for high-level Petri Nets

Recent News in the Petri Nets World

[January 23, 2021](#): FMICS 2021 Call for Papers

[January 23, 2021](#): Special Issue of International Journal of Parallel, Emergent and Distributed Systems: Petri/Sleptsov Net Based Technology of Programming for Parallel, Emergent and Distributed Systems

[January 20, 2021](#): CFP: International Workshop on Petri Nets and Software Engineering , PNSE'21, Paris, France, June, 2021

[January 19, 2021](#): Assistant Professor in Formal Methods @ DTU Compute

[January 19, 2021](#): Two open Ph.D. positions in Probabilistic Verification Methodologies for Synthetic Biology and Nanotechnology

[January 18, 2021](#): [Vardi-list] Postdoc Position - Analysis Techniques for DNNs

[January 18, 2021](#): Petri Nets 2021: deadline extension

[January 18, 2021](#): MODEL CHECKING CONTEST 2021 - (2/2) - CALL FOR TOOLS

[January 16, 2021](#): Call for Graduate Symposium: Diagrams 2021

[January 15, 2021](#): CFP ATAED 2021

[January 14, 2021](#): MODEL CHECKING CONTEST 2021 - (1/2) - CALL FOR MODELS

Activate Windows
Go to Settings to activate Windows.

54°F Rain showers 12:14 PM 2/26/2023


Modeling system Tina

- **Laboratory for Analysis and Architecture of Systems (LAAS), Toulouse, France –**
<http://projects.laas.fr/tina/>
- **Winner of Model Checking Contest in Paris –**
<https://mcc.lip6.fr/>
- **Draw or generate models and analyse their properties**


Tina LAAS CNRS

The TINA toolbox Home Page - T x +

← → ↻ projects.laas.fr/tina/home.php



Time petri Net Analyzer



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About Tina

TINA (Time petri Net Analyzer) is a toolbox for the editing and analysis of **Petri Nets**, with possibly inhibitor and read arcs, **Time Petri Nets**, with possibly priorities and stopwatches, and an extension of Time Petri Nets with data handling called **Time Transition Systems**. TINA has been developed in the OLC, then VerTICS, research groups of LAAS/CNRS. General Petri nets information can be found on the [Petri Nets World](#) site.

The TINA toolbox includes the tools:

nd (NetDraw): Editor and GUI for Petri nets, Time Petri Nets and Automata.

Handles graphically or textually described nets or automata. Interfaced with analysis tools below. Includes drawing facilities for nets and automata and a stepper simulator for nets.

tina: Construction of reachability graphs.

From nets described in textual or graphical form, produces transition systems abstracting their behavior in human readable form or in various formats for available model checkers and equivalence checkers. This tool is described in [4] and [9]: depending on options retained, it builds:

- The coverability graph of a Petri net, by the Karp and Miller technique.
- The marking graph of a bounded Petri net.
- Partial marking graphs of a Petri net, by the covering steps methods of [6][7], the method of persistent sets, or several combinations of them explained in [8].
- Various state space abstractions for Time Petri nets (state class graphs), following the techniques discussed in [1][2][3][5]. Depending on the option selected, the construction preserves markings, states, LTL properties, or CTL* properties of the concrete state space of the Time Petri net.

sift: Construction and checking of reachability graphs.

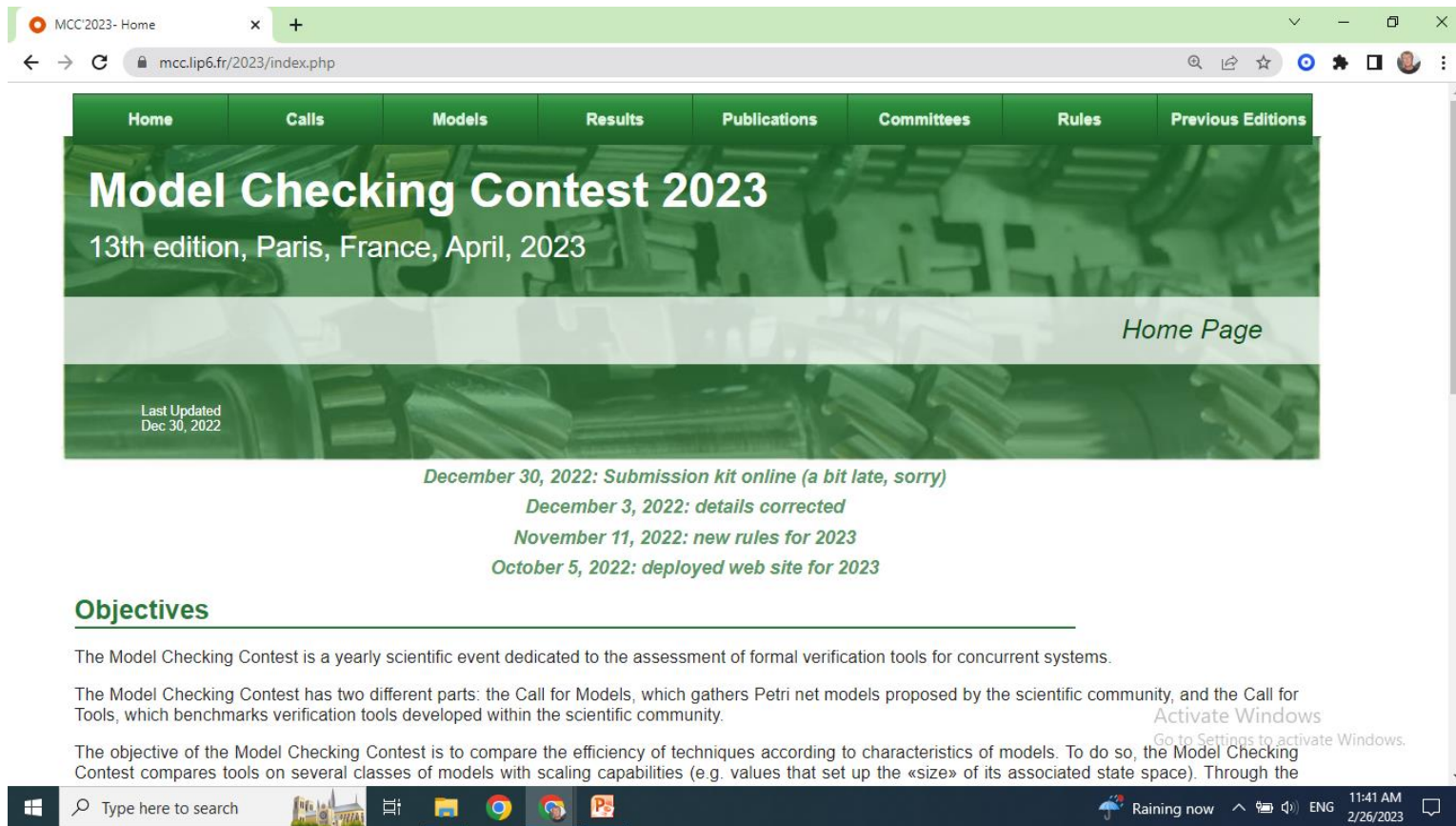
Sift is a specialized version of tina supporting in addition on the fly verification of reachability properties. It offers less options than tina but is typically

Activate Windows
Go to Settings to activate Windows.

Type here to search

54°F Rain showers 12:17 PM 2/26/2023

MCC Paris 6 University



The screenshot shows a web browser window with the address bar displaying 'mcc.lip6.fr/2023/index.php'. The page has a green header with navigation links: Home, Calls, Models, Results, Publications, Committees, Rules, and Previous Editions. The main content area features a large green banner with the text 'Model Checking Contest 2023' and '13th edition, Paris, France, April, 2023'. Below this, there is a section titled 'Home Page' and a list of updates: 'December 30, 2022: Submission kit online (a bit late, sorry)', 'December 3, 2022: details corrected', 'November 11, 2022: new rules for 2023', and 'October 5, 2022: deployed web site for 2023'. The page also includes a section for 'Objectives' and a Windows taskbar at the bottom.

MCC'2023- Home

mcc.lip6.fr/2023/index.php

Home Calls Models Results Publications Committees Rules Previous Editions

Model Checking Contest 2023

13th edition, Paris, France, April, 2023

Home Page

Last Updated
Dec 30, 2022

December 30, 2022: Submission kit online (a bit late, sorry)
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Objectives

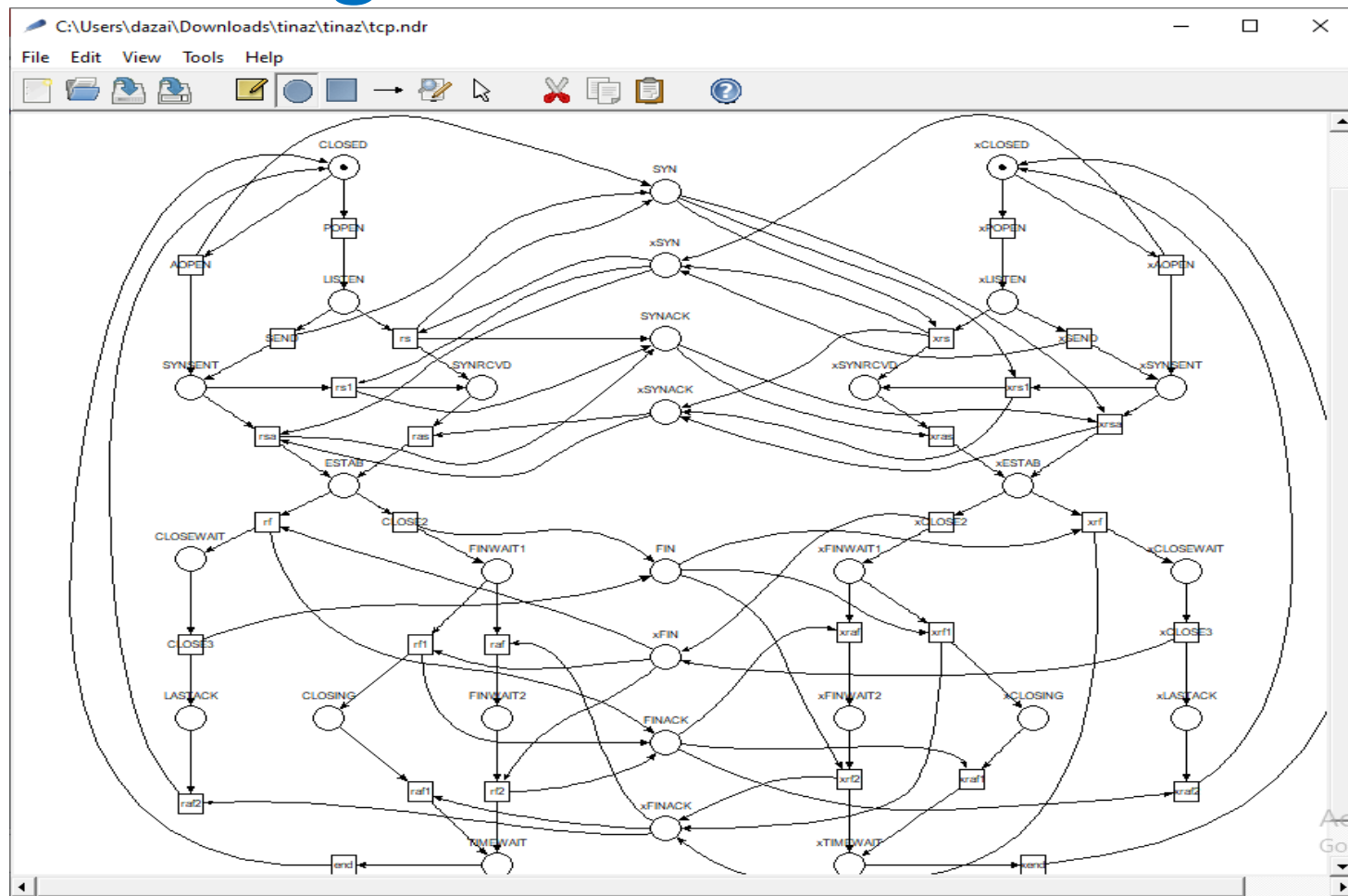
The Model Checking Contest is a yearly scientific event dedicated to the assessment of formal verification tools for concurrent systems.

The Model Checking Contest has two different parts: the Call for Models, which gathers Petri net models proposed by the scientific community, and the Call for Tools, which benchmarks verification tools developed within the scientific community.

The objective of the Model Checking Contest is to compare the efficiency of techniques according to characteristics of models. To do so, the Model Checking Contest compares tools on several classes of models with scaling capabilities (e.g. values that set up the «size» of its associated state space). Through the

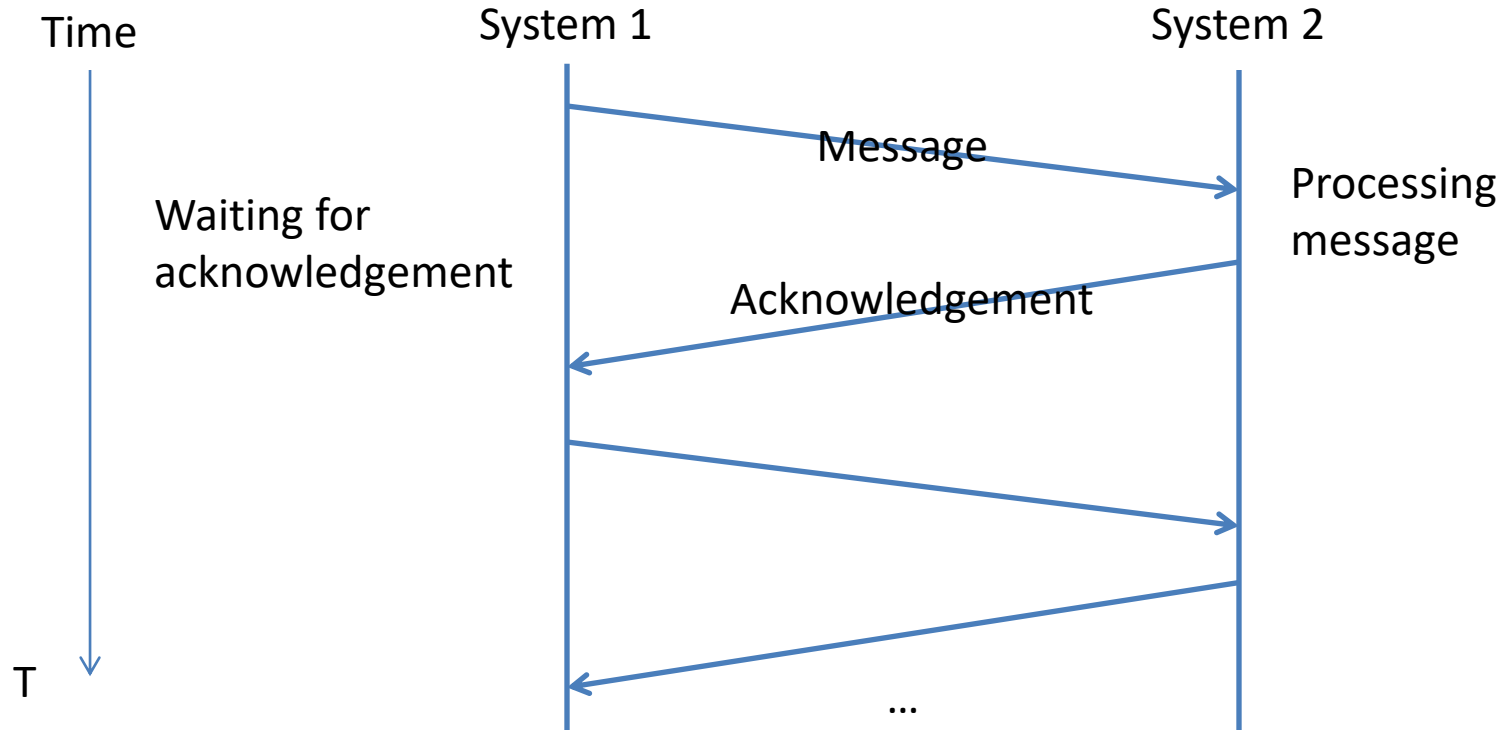
Windows taskbar: Type here to search, Raining now, 11:41 AM, 2/26/2023

Tina integrated environment – nd

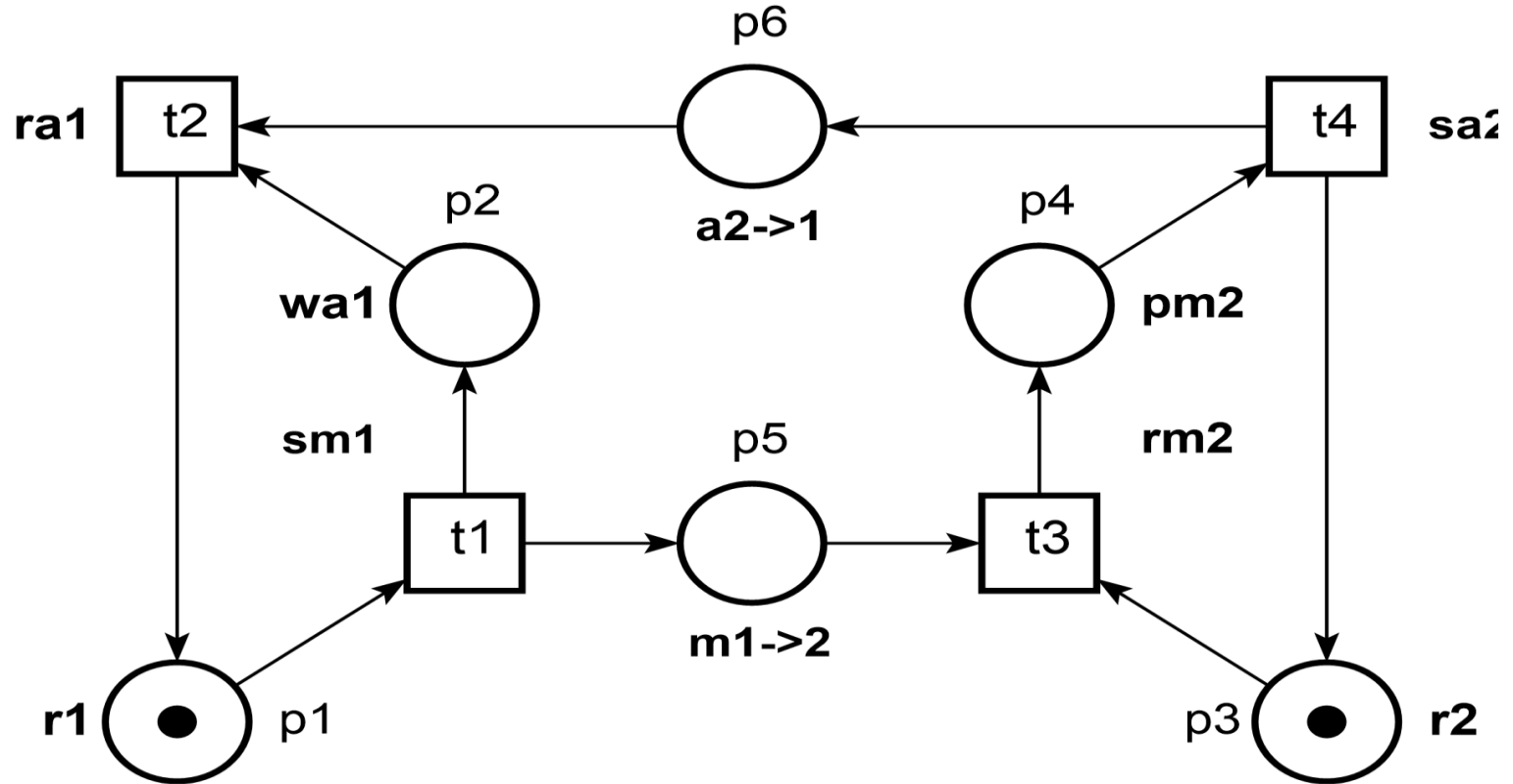


Unidirectional transmission of messages with acknowledgements (SimAck)

Case study



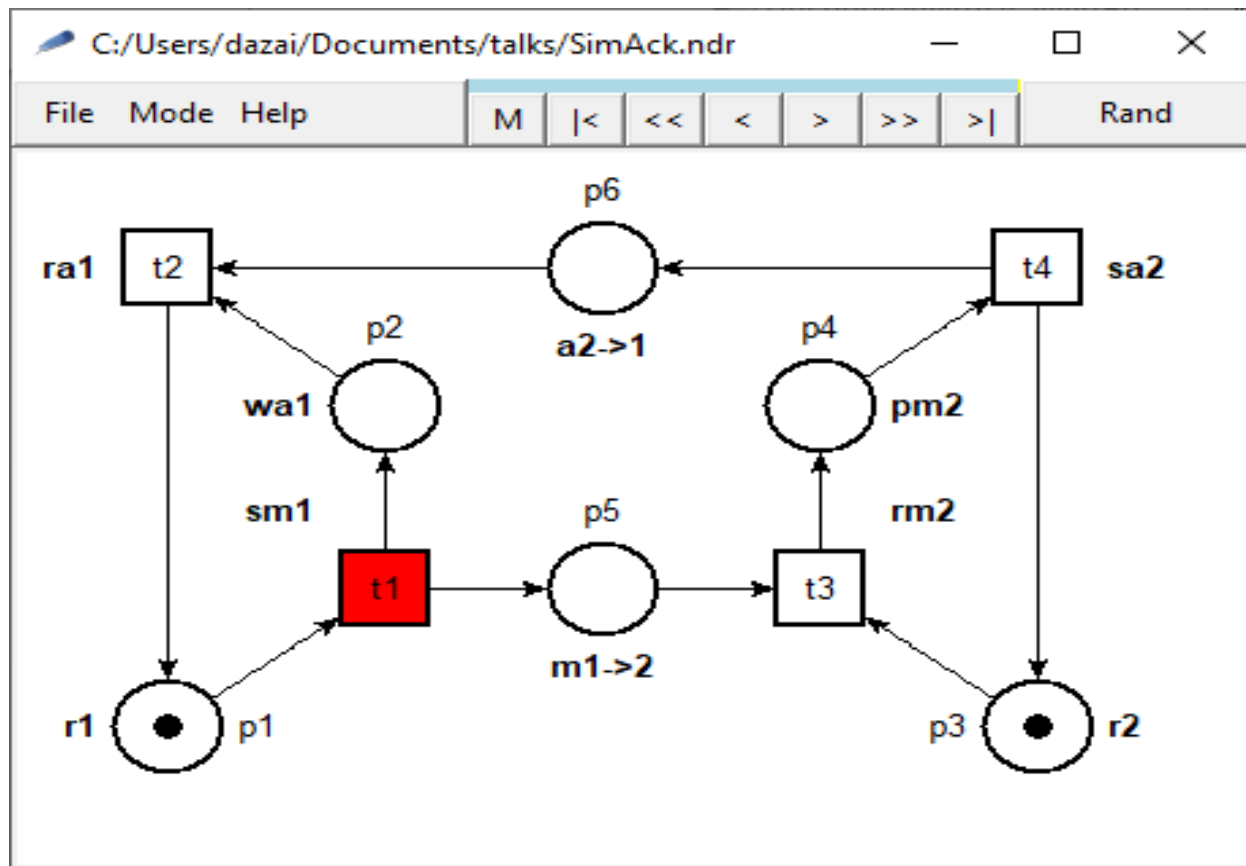
Model of protocol SimAck



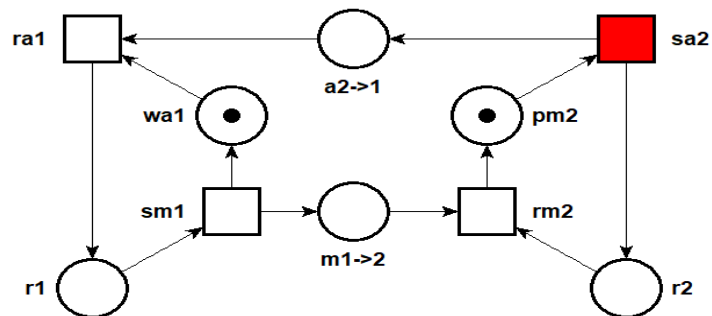
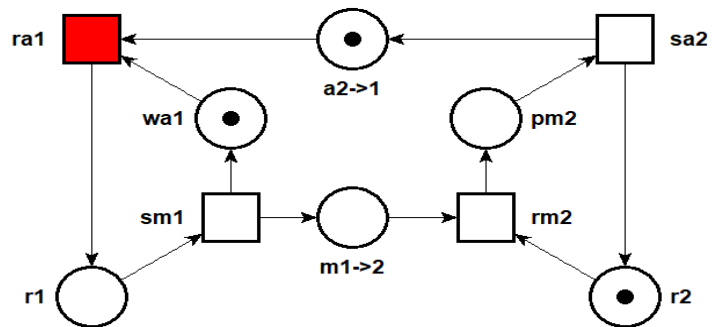
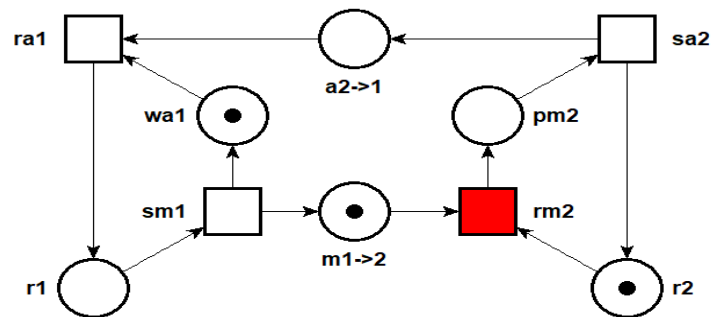
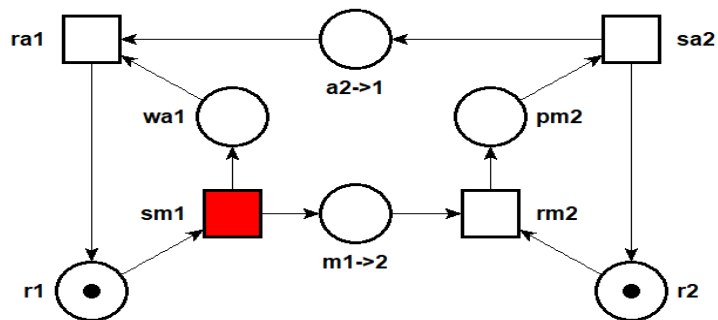
Notation of vertices

Notation	Description
r	system is ready
sm	send message
rm	receive message
wa	wait acknowledgement
pm	process message
sa	send acknowledgement
ra	receive acknowledgement
m	message
a	acknowledgement

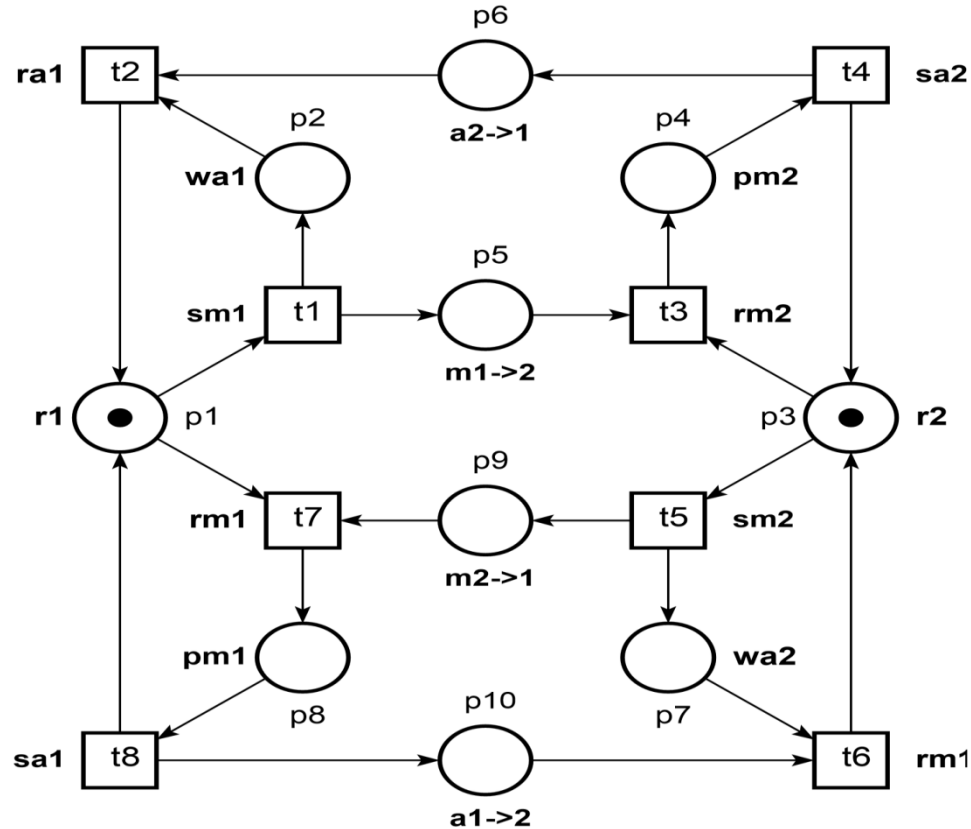
Step-by-step simulation Tool



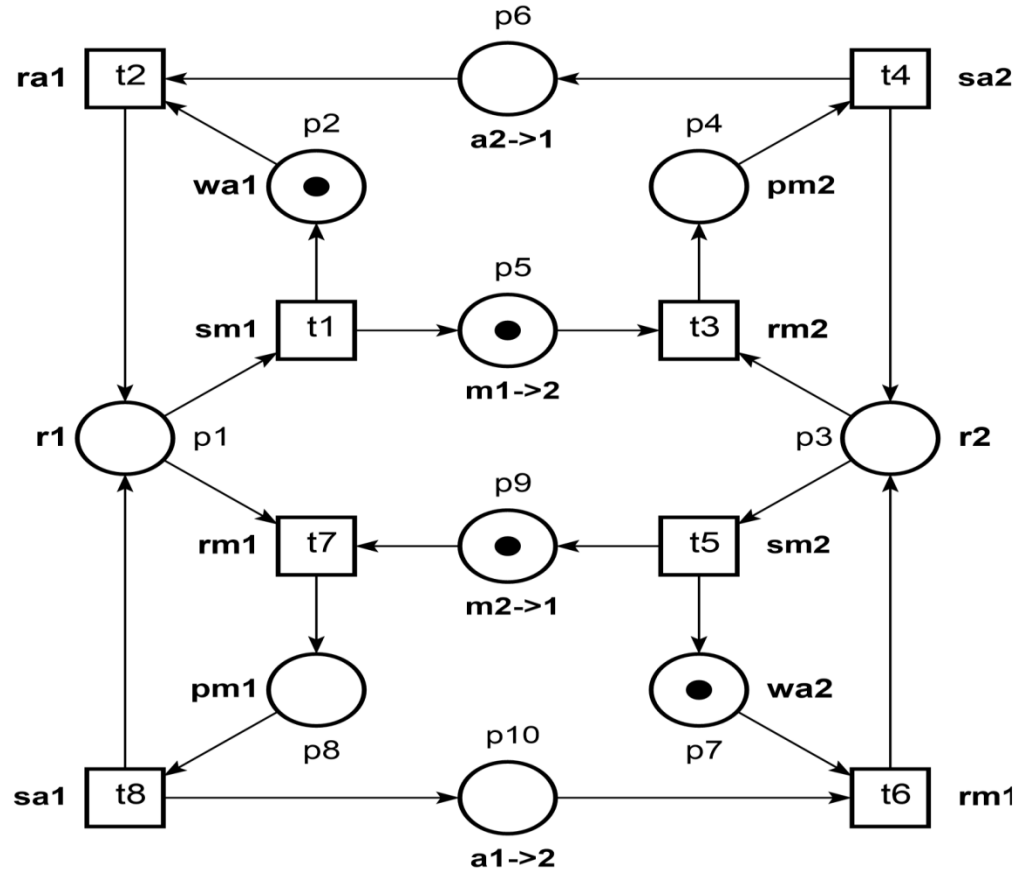
Net behavior



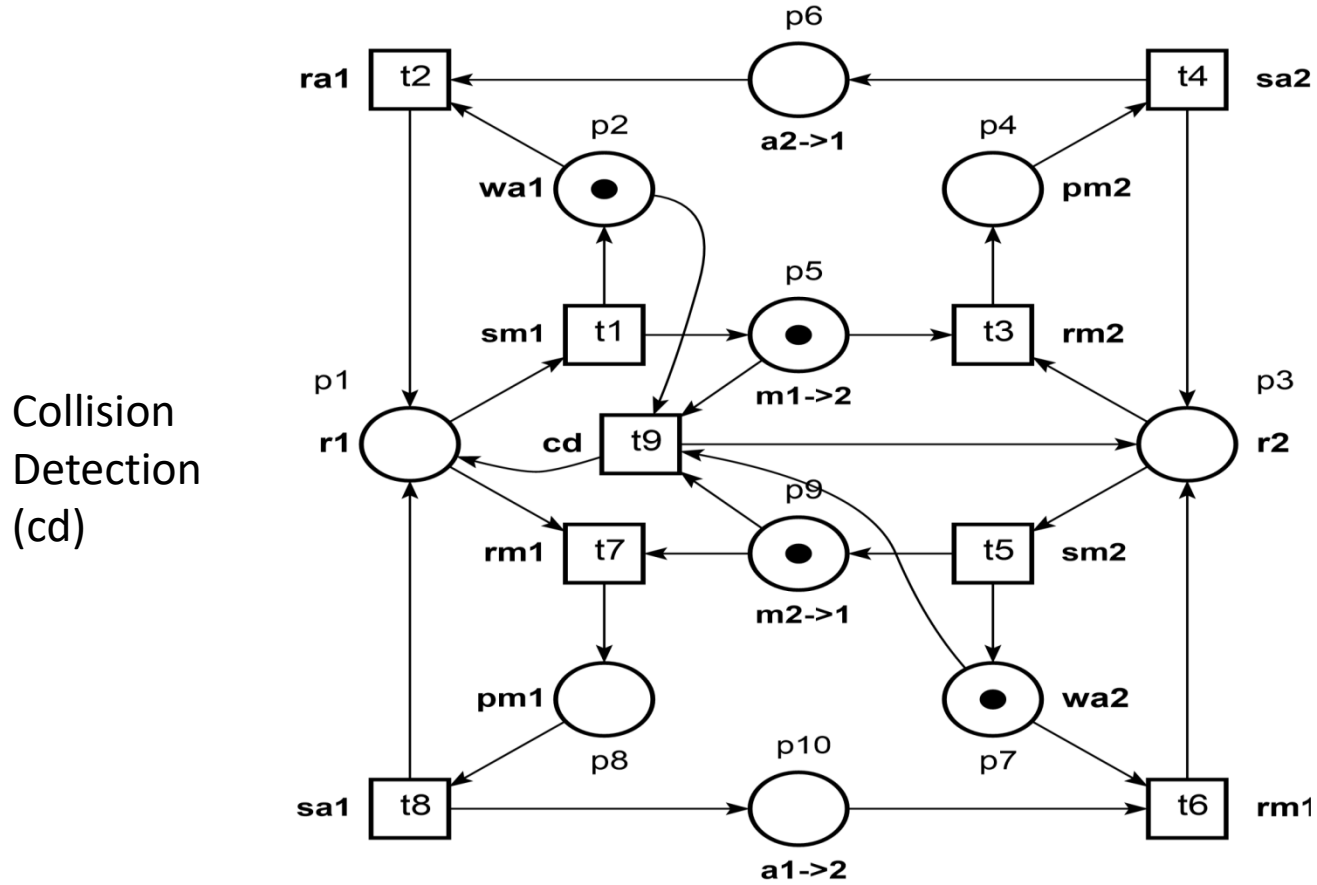
Bidirectional transmission of messages with acknowledgements (DupAck)



Deadlock

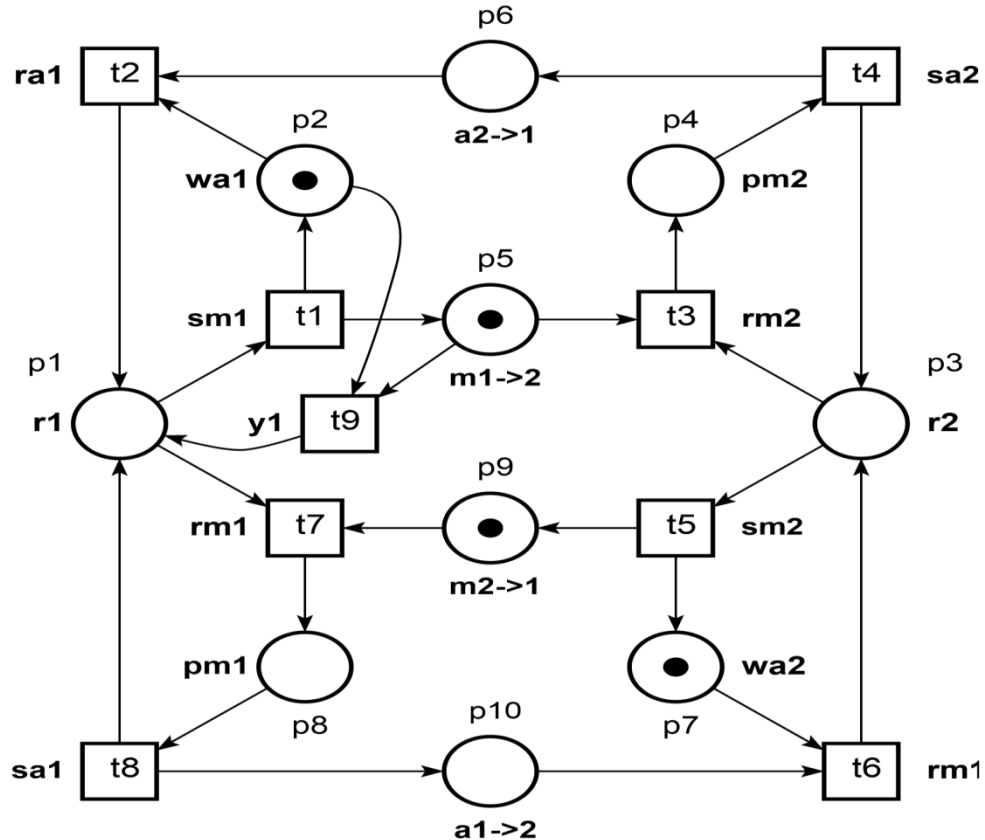


Modified protocol: collision detection



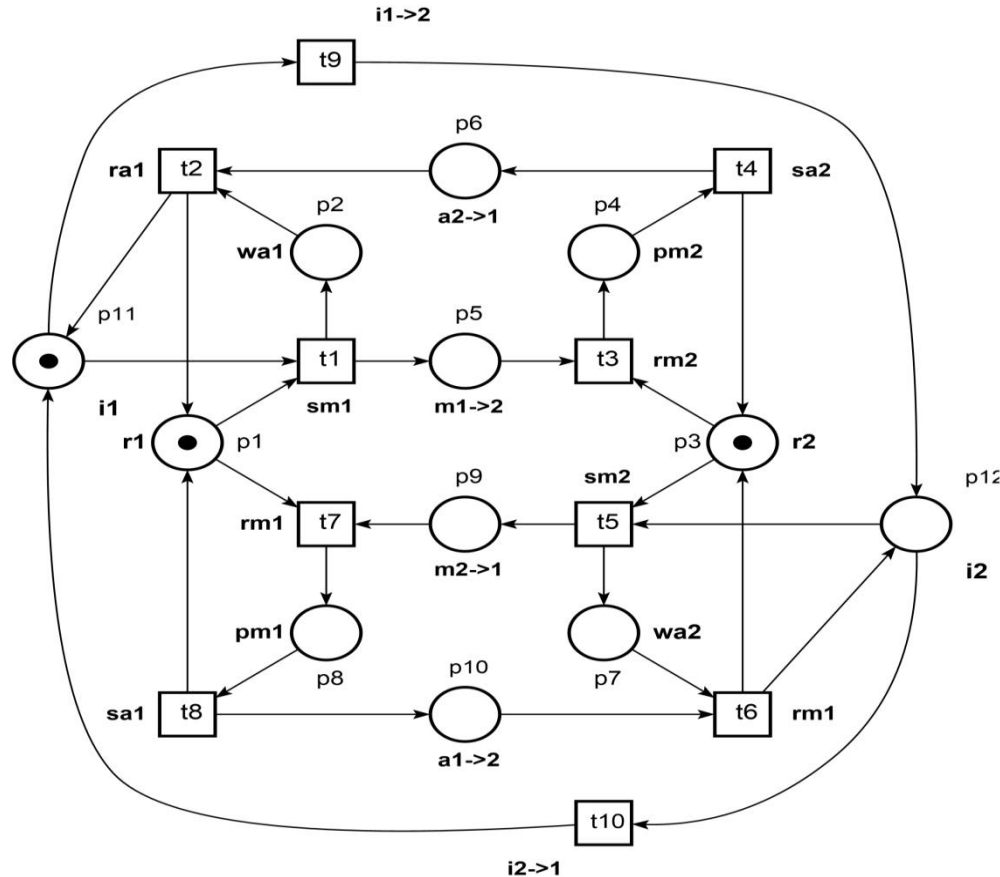
Modified protocol: one yielding system

Yield
(y)



Modified protocol: cyclic transmission of invitation

Token Ring –
Invitation
(i)



Methods of Petri net analysis

- **Graphs of reachable and covering markings**
- **Fundamental equation of ne and linear invariants– solving linear systems in nonnegative integer numbers**
- **Siphons and traps – solving logical systems**
- **Reduction – transformation decreasing net size and preserving properties**
- **Decomposition – division into parts**

References

- [Zaitsev D.A. Clans of Petri Nets: Verification of protocols and performance evaluation of networks, LAP LAMBERT Academic Publishing, 2013, 292 p.](#)
- Zaitsev D.A. [Verification of Protocol BGP via Decomposition of Petri Net Model into Functional Subnets](#) // Proceedings of the Design, Analysis, and Simulation of Distributed Systems Symposium, April 2-8, 2005, San Diego, USA, p. 72-78.
- Zaitsev D.A. [Verification of protocol TCP via decomposition of Petri net model into functional subnets](#). Proceedings of the Poster session of 12th Annual Meeting of the IEEE / ACM International Symposium on Modeling, Analysis, and Simulation of Computer and Telecommunication Systems, October 5-7, 2004, Volendam, Netherlands, p. 73-75.