

# Markets: a paradigm for agents in the digital world – the principles

**Peter Fettke and Wolfgang Reisig**



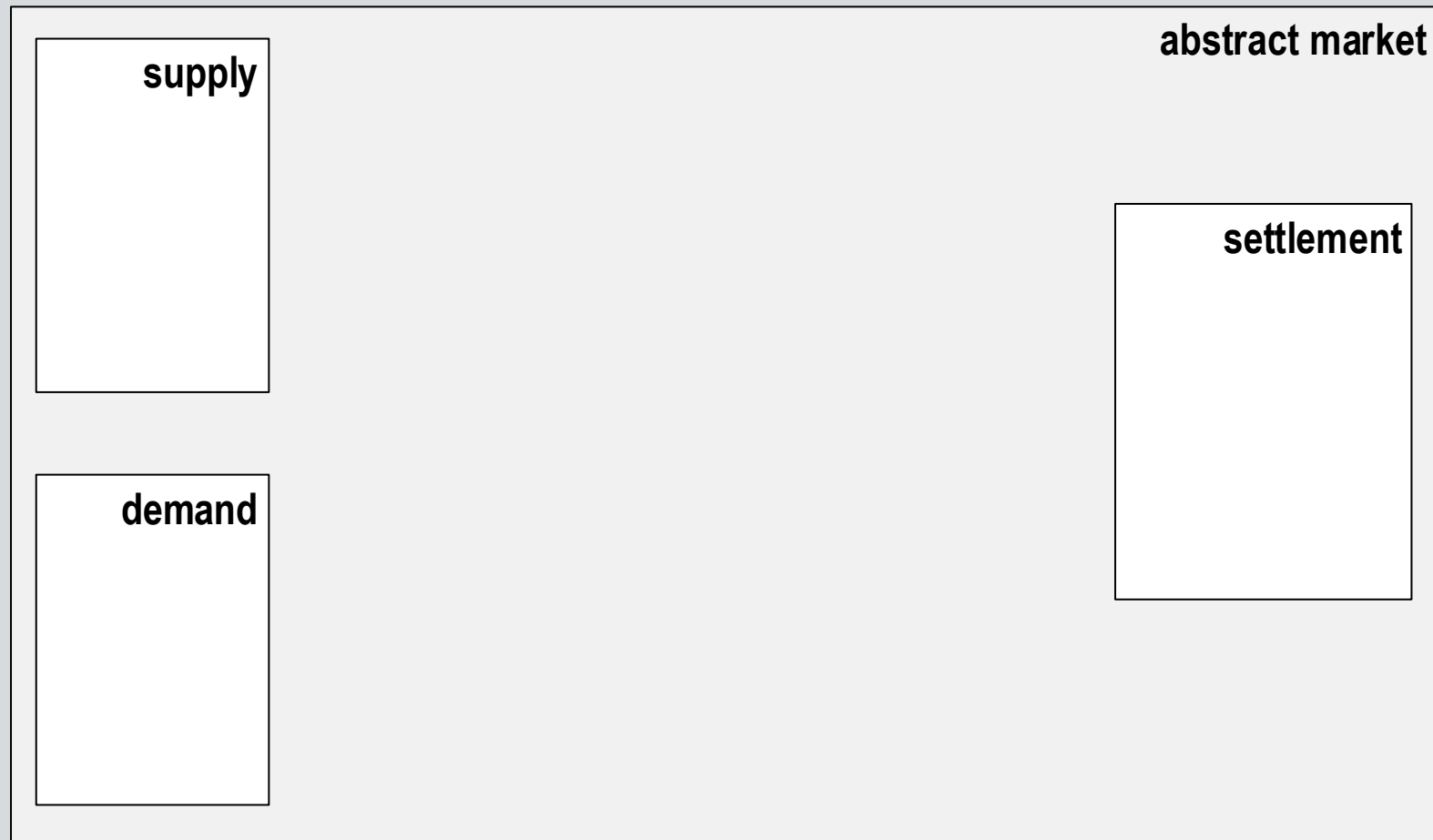
# Agenda

This talk in a nutshell

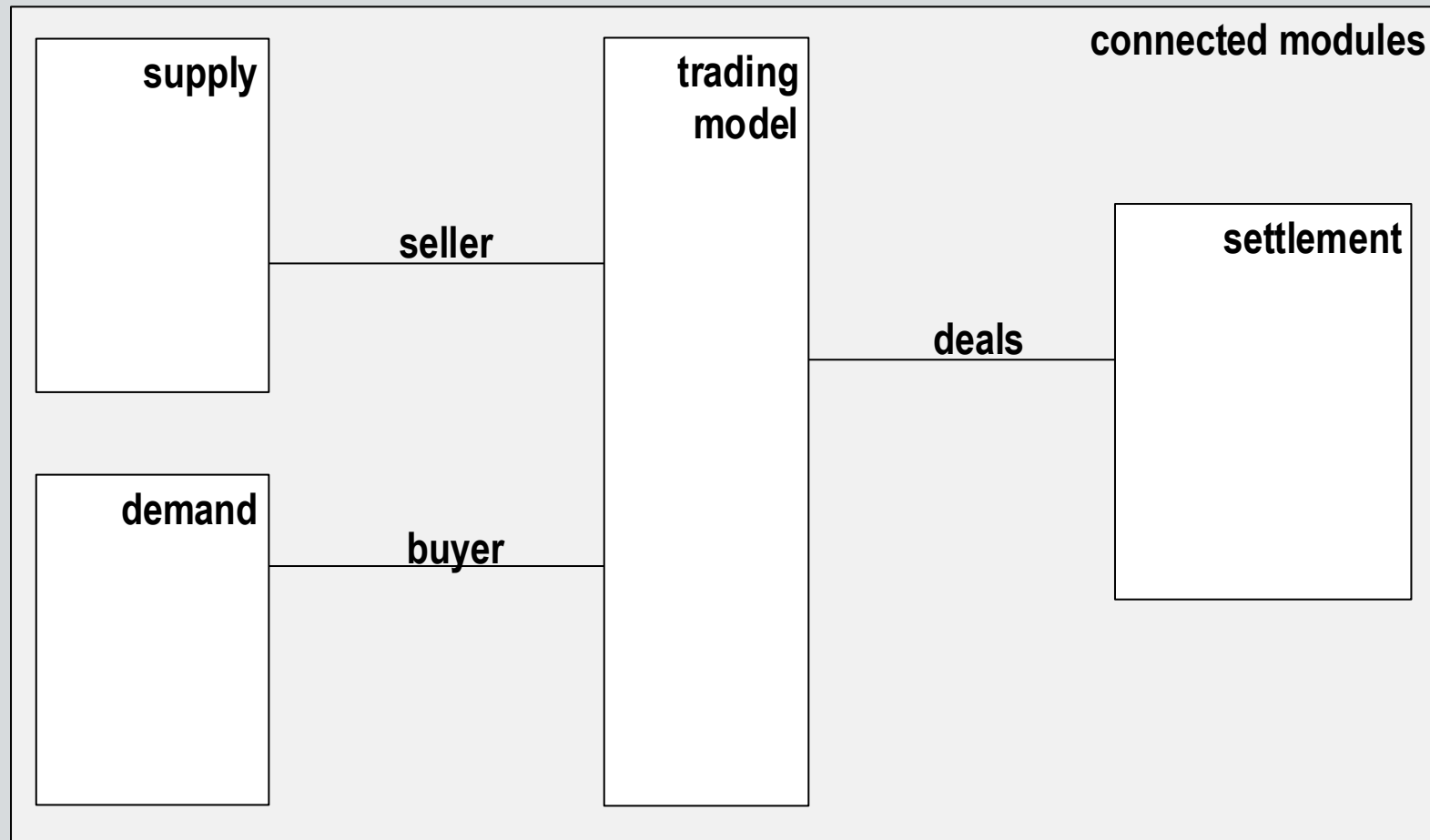
1. Understanding the digital world
2. Modeling markets
3. Conclusions



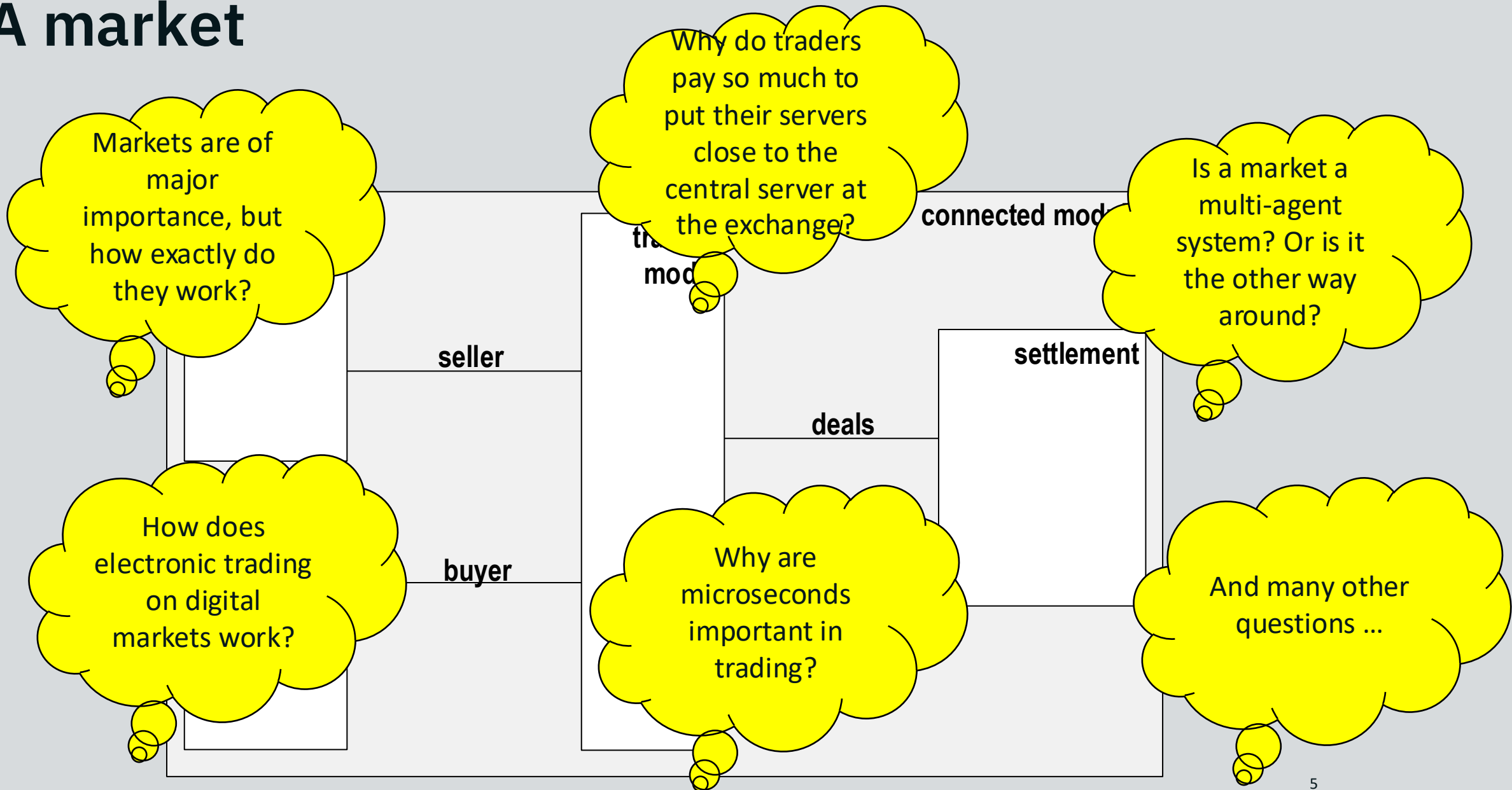
# A market



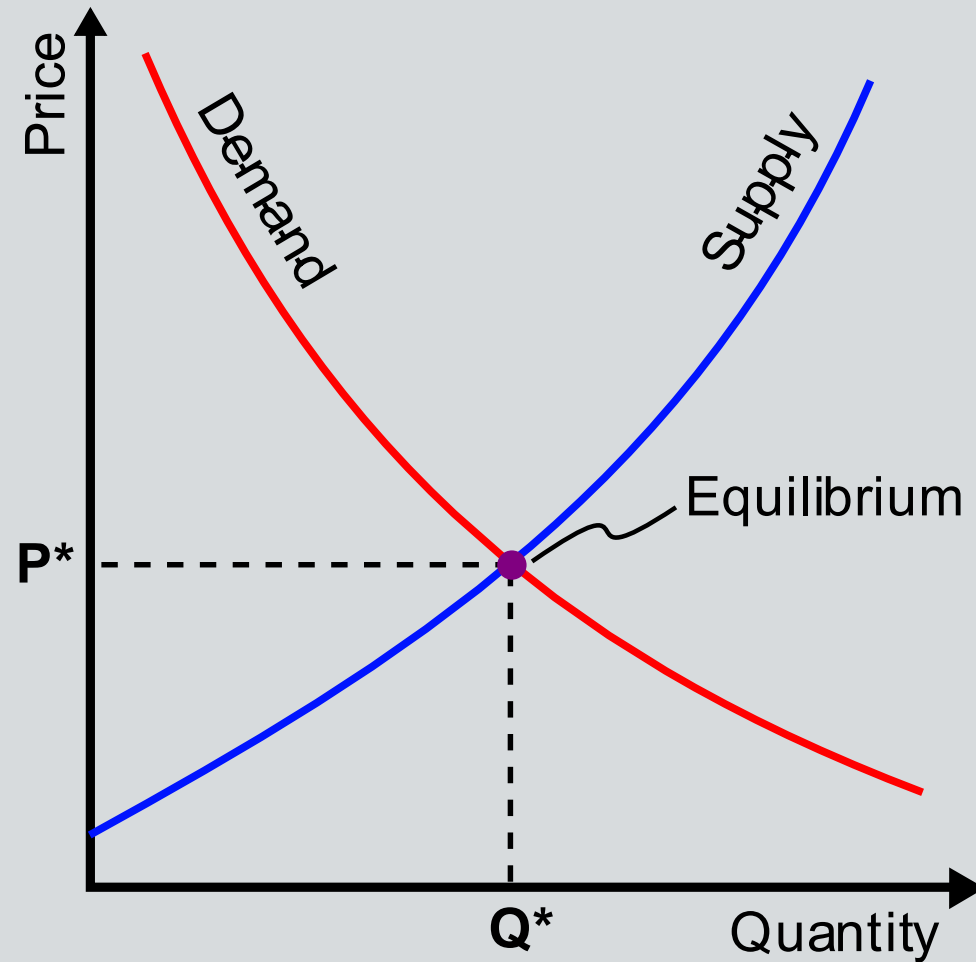
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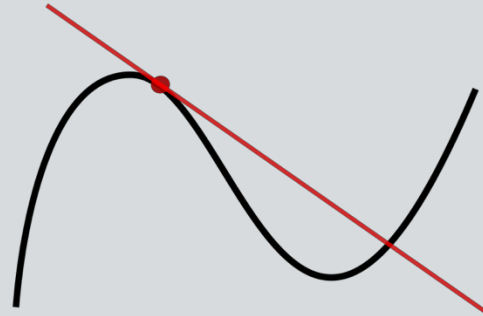
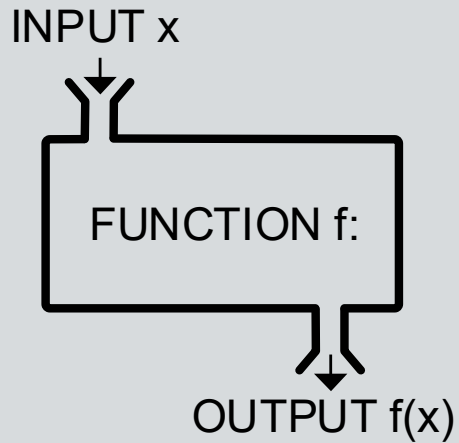
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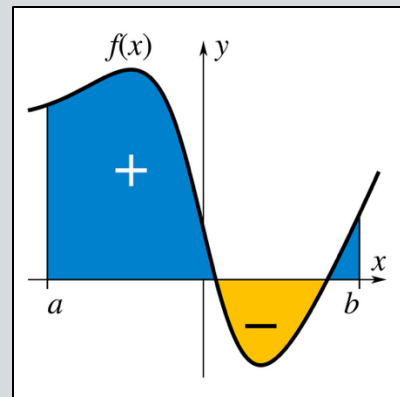
# A typical market model



# The Calculus: the paradigm to study change and causality



differential  
calculus

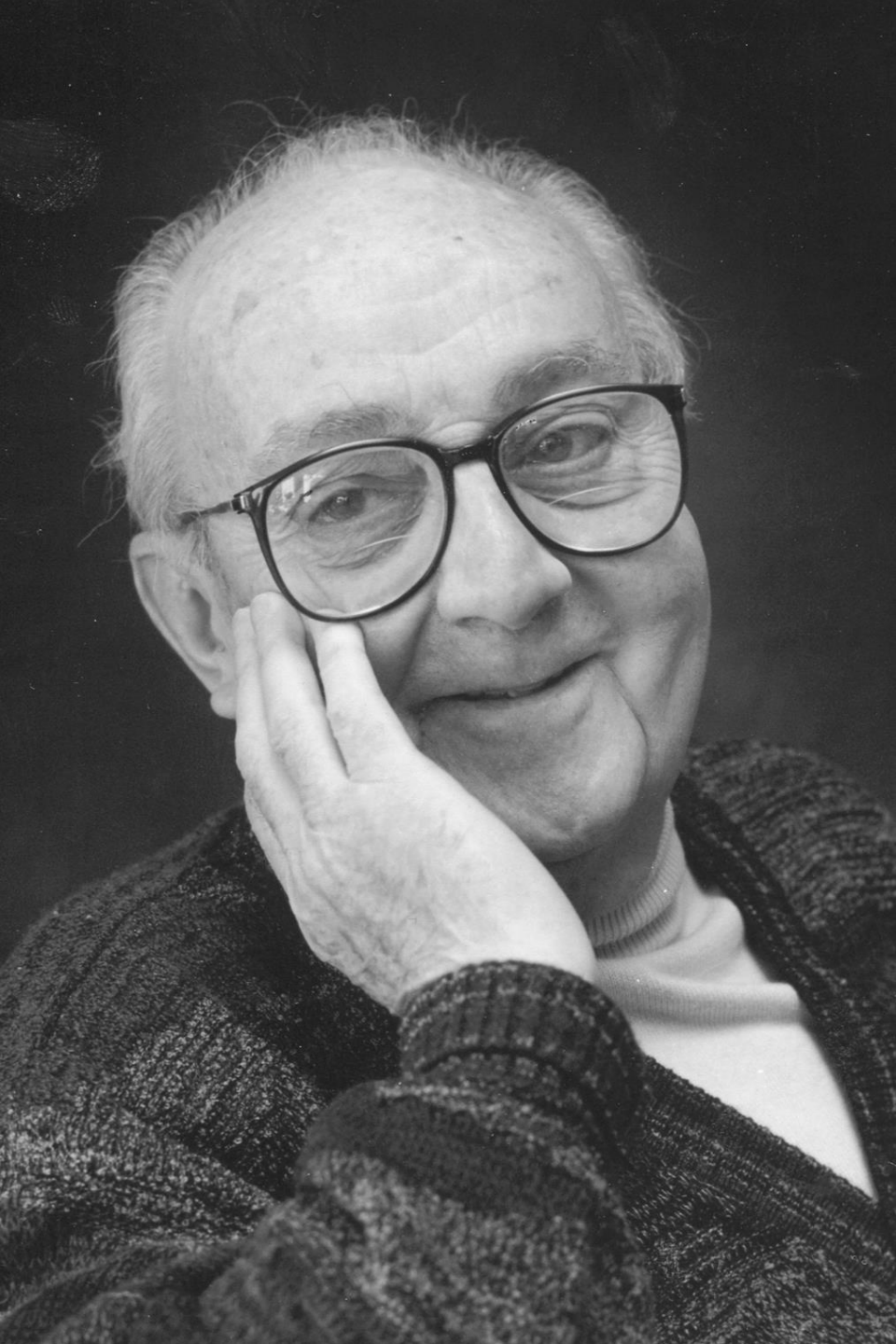


integral  
calculus



John von Neumann (1947)

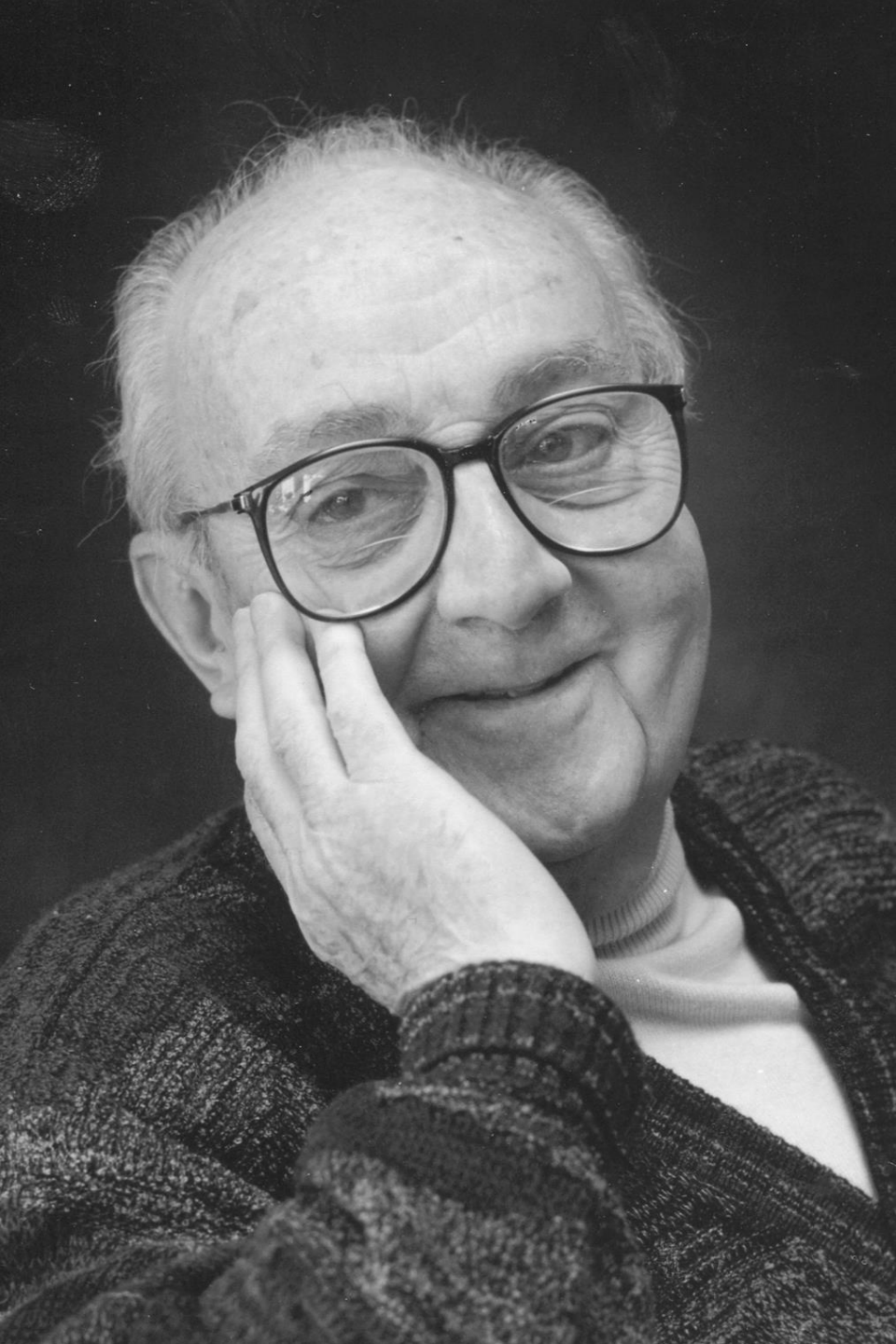
“The calculus was the first achievement of modern mathematics and it is difficult to overestimate its importance.”



**“All models are wrong”**

**George Box (1919-2013)**





**“All models are wrong  
but some are useful”**

**George Box (1919-2013)**



**We argue that  
new models are  
needed to study  
the digital world!**

“All models are wrong  
but some are useful”

George Yule (1919-2013)

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# We live in a digital world

“digital avatars, digital banking, digital books, digital communication, digital data, digital education, digital entertainment, digital health, digital identities, digital manufacturing, digital media, digital metering, digital money, digital music, digital phones, digital processes, digital production, digital products, digital publishing, digital retail, digital service machines, digital shops, digital sports, digital systems, digital teaching, digital television, digital tickets, digital twins, digital worlds, et cetera.”

Source: Fettke, Reisig (2014)

# We live in a digital world

The digital world  
is no longer  
*analog*. But what  
are its core  
aspects?

(Electronic) Data?

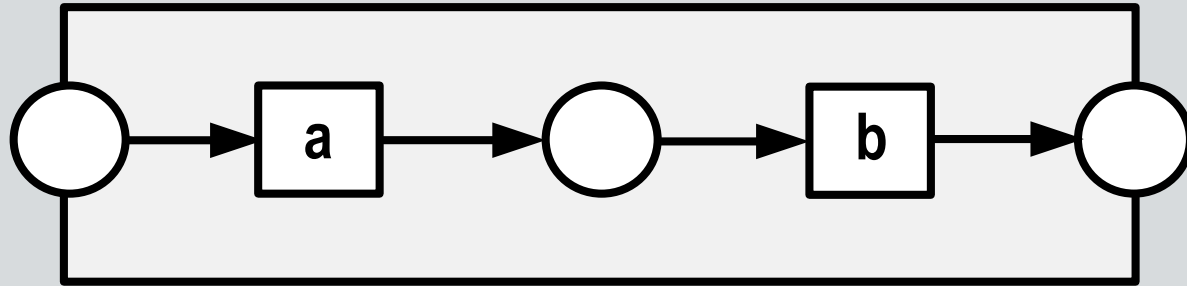
(Virtual)  
Systems?

(Automated)  
Actions?

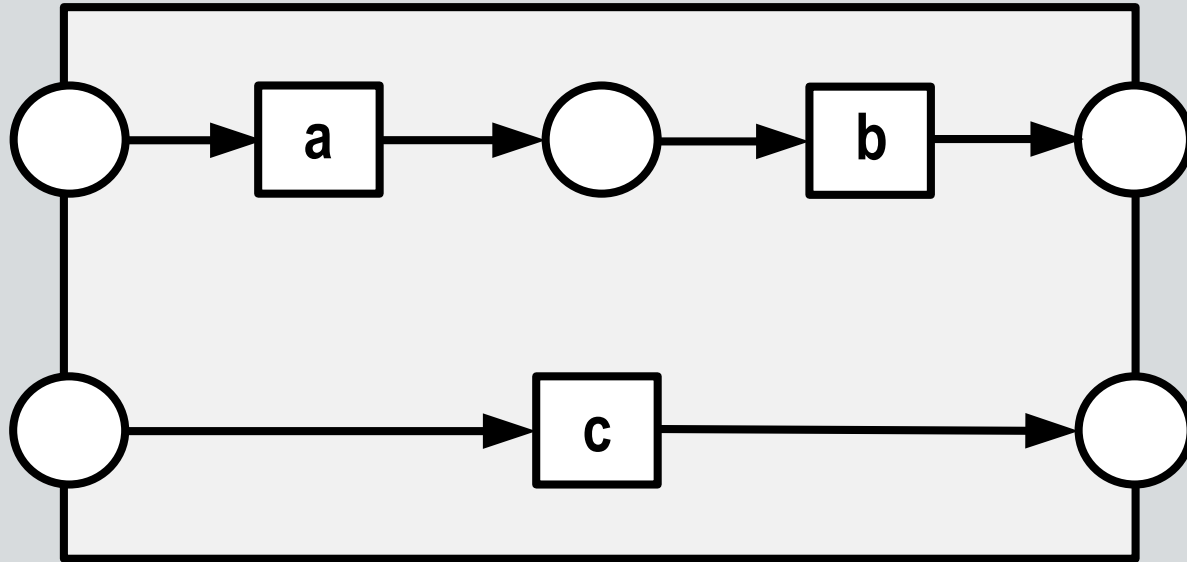
Or something  
else?

Source: Fetting et al., 2017

# Core of the digital world: discrete steps

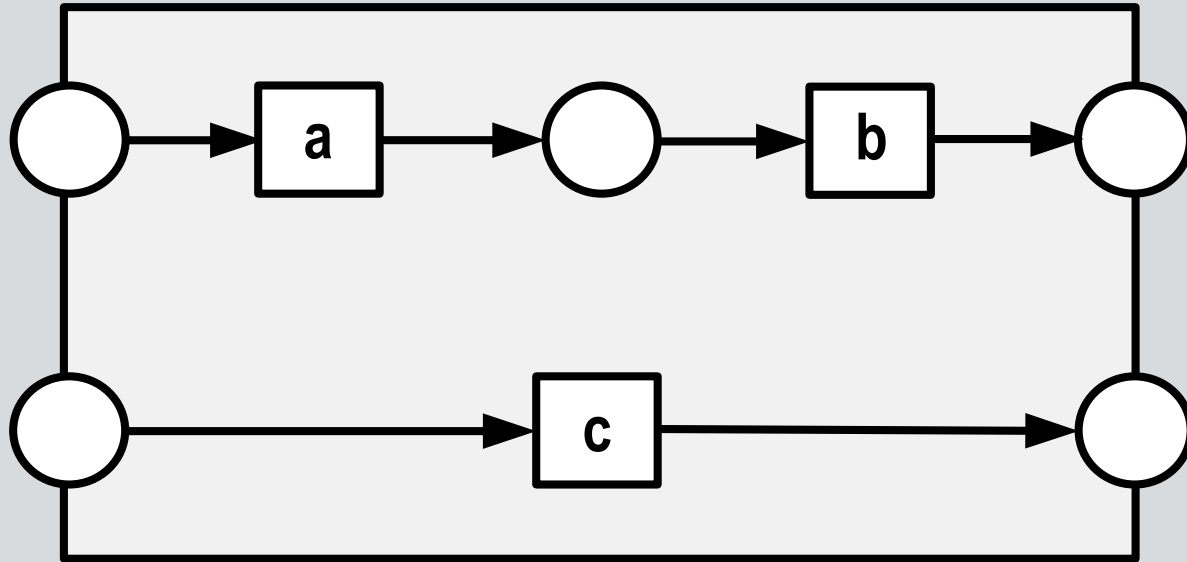


# Core of the digital world: discrete steps





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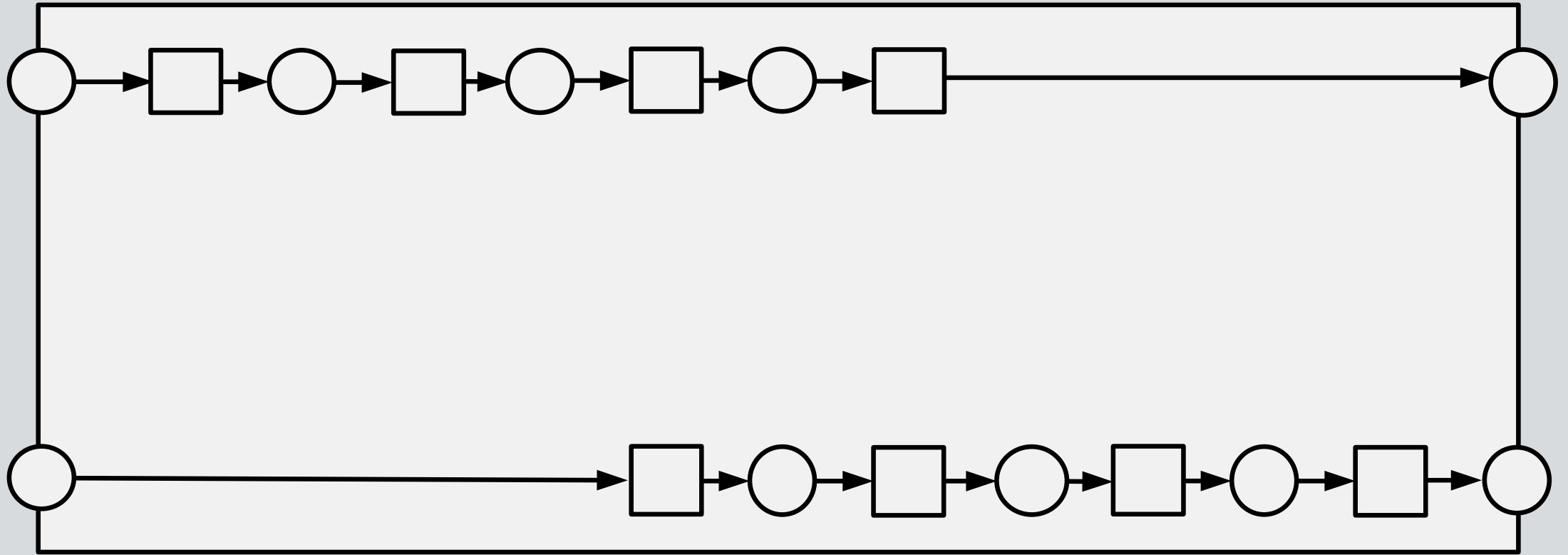


## Key observations

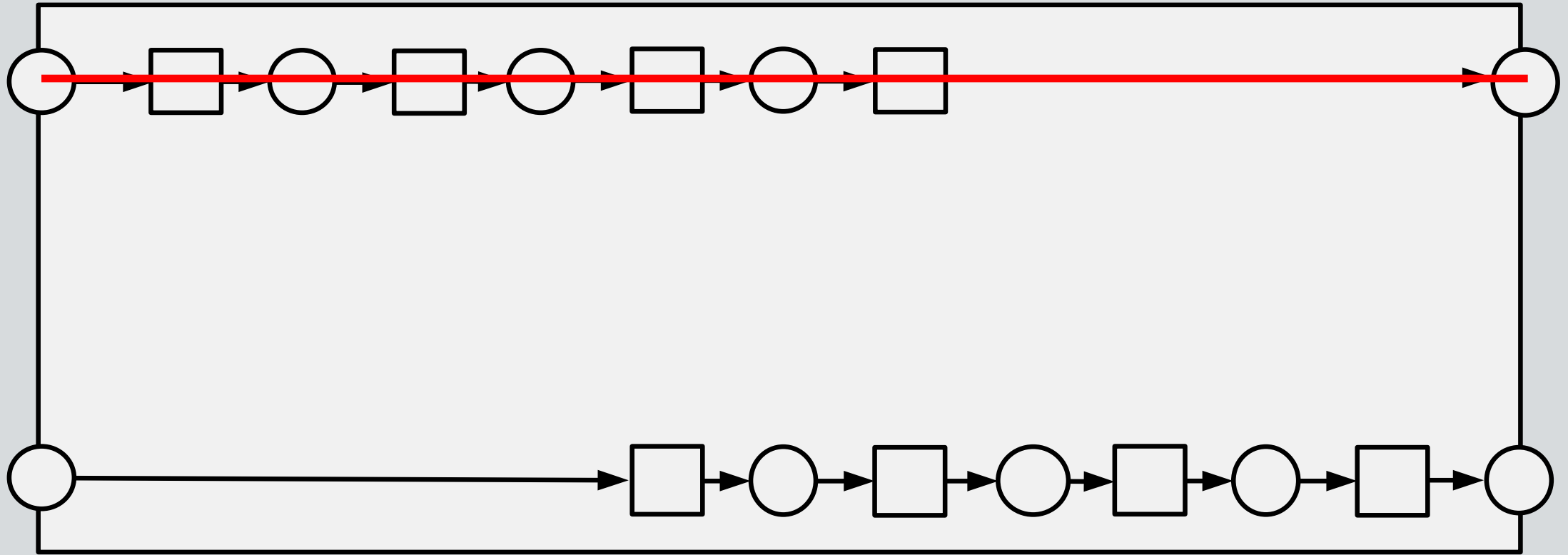
- *a* is *independent* of *c* and *c* is *independent* of *b*
- but *a* is *not independent* of *b*, in fact, *a causes b*
- causal independence is *not* transitive



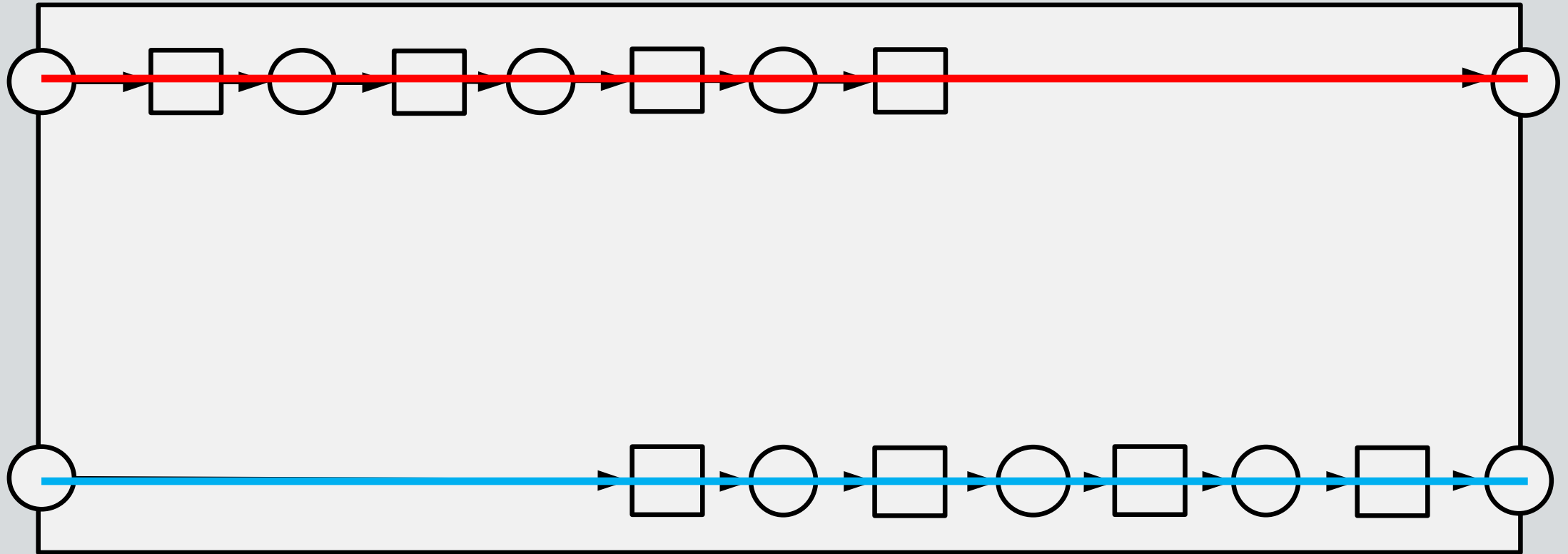
# Cause, effect and independence: a deeper look



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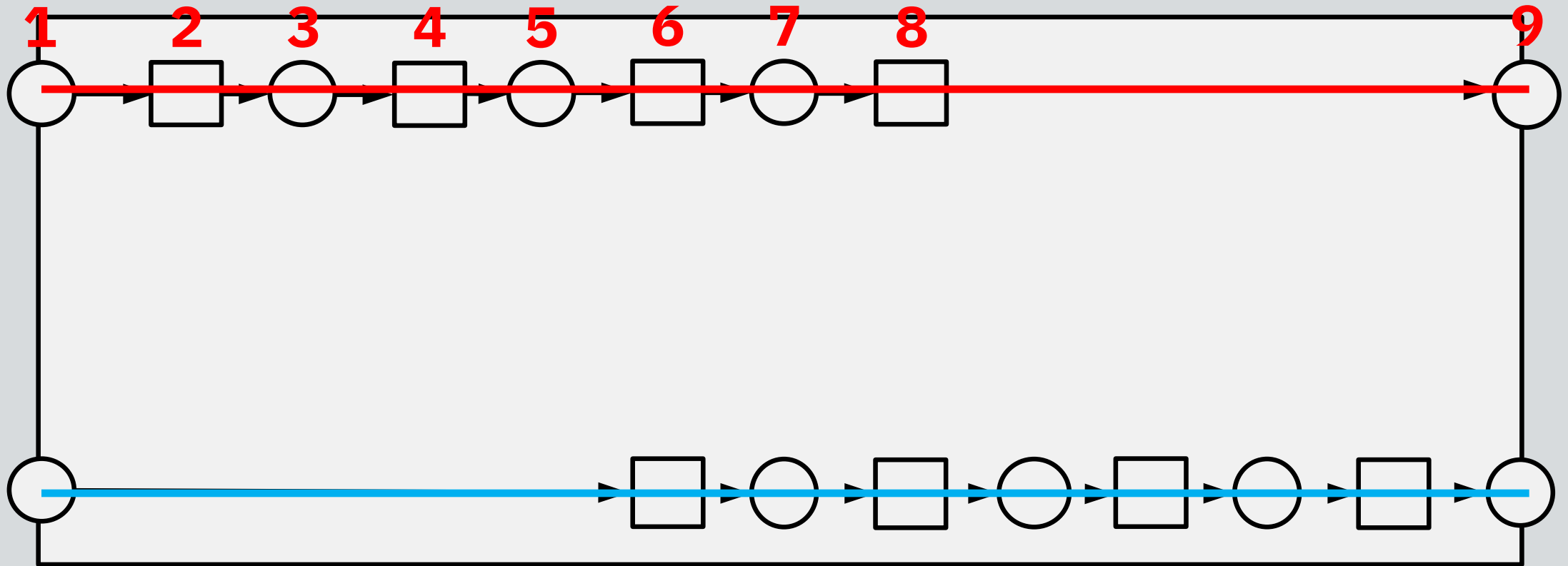


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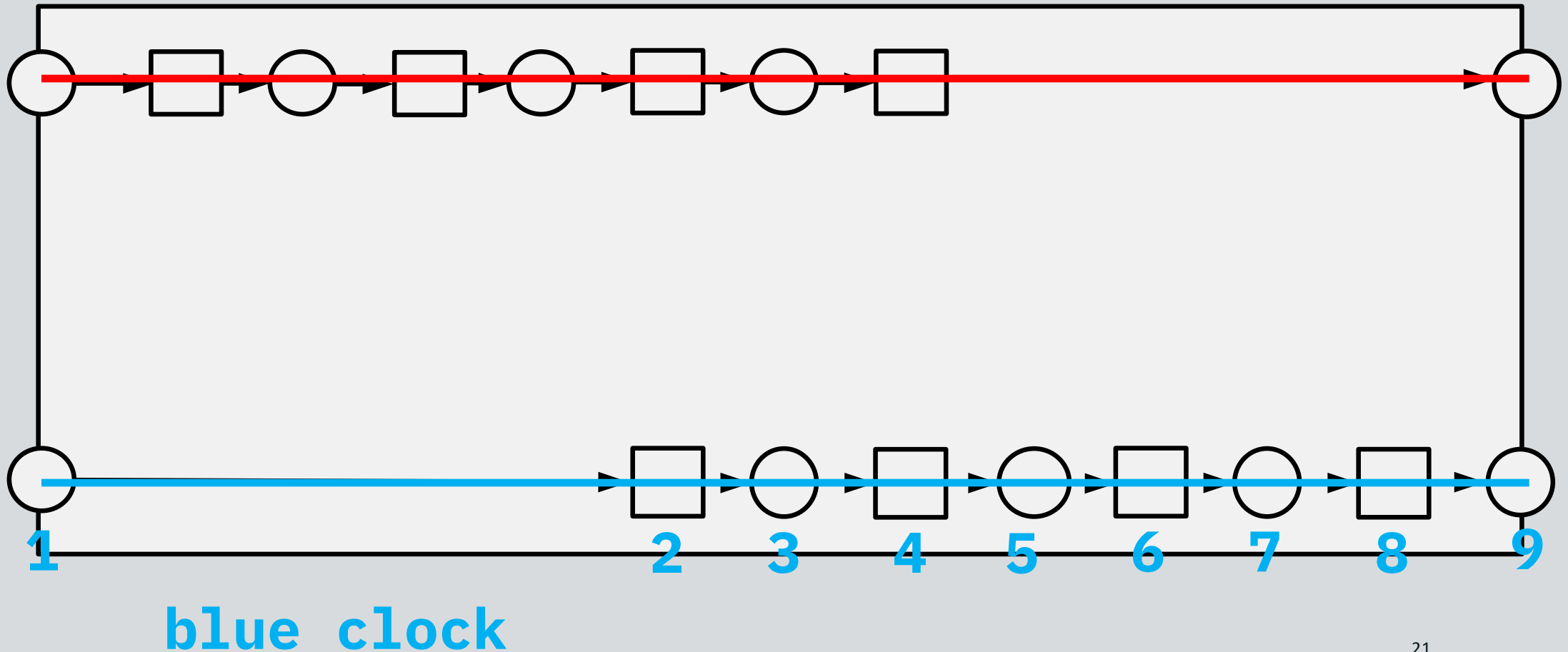


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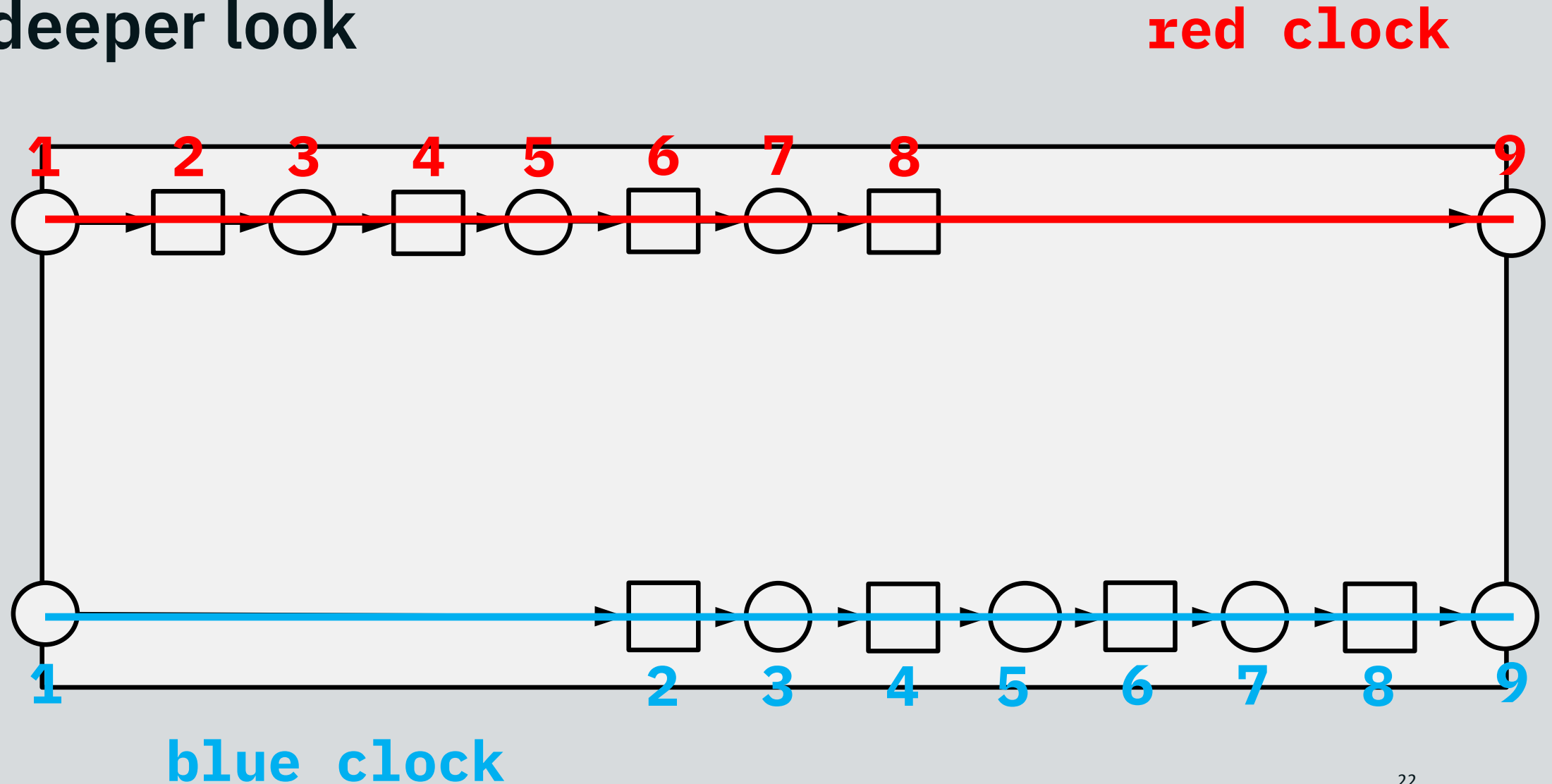
red clock



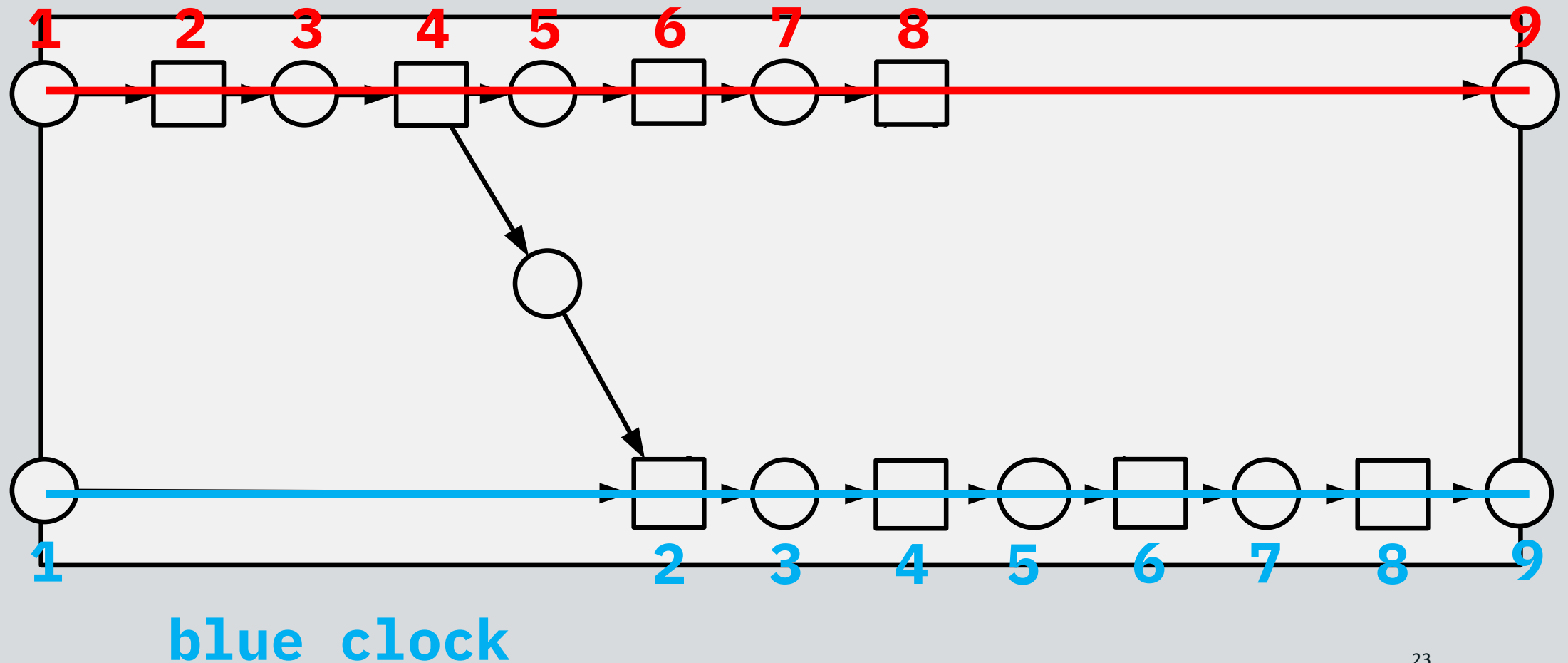
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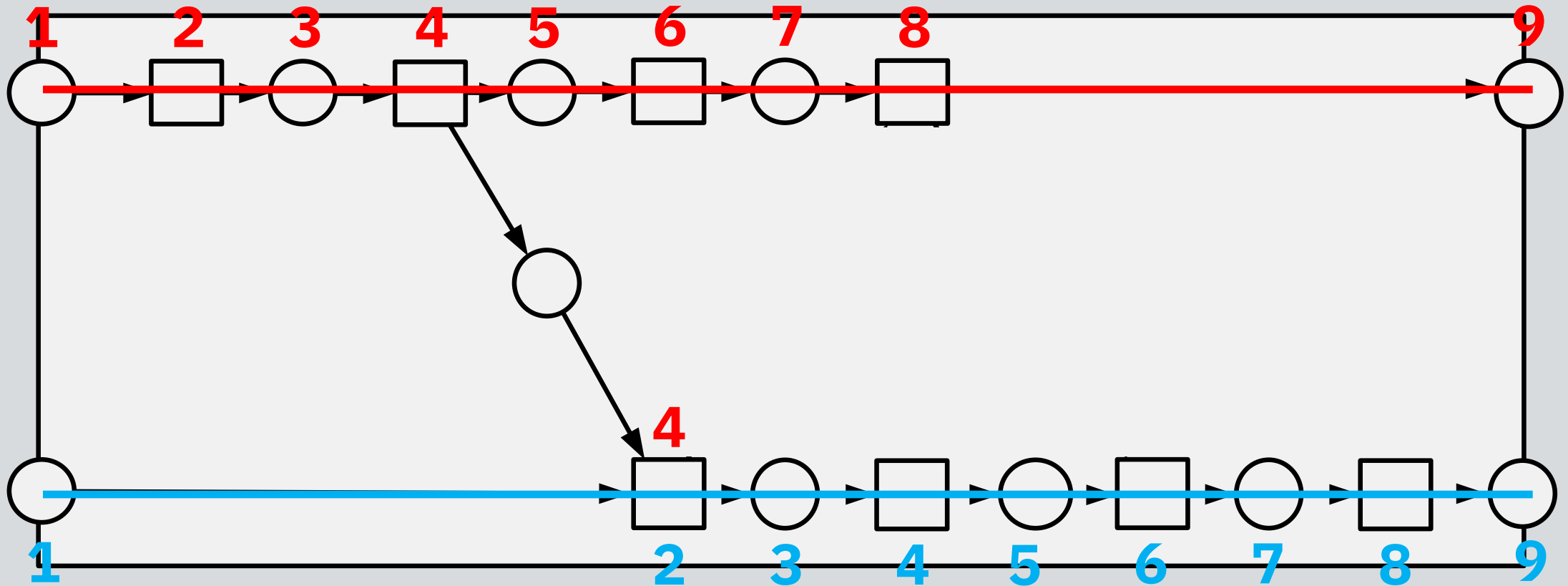


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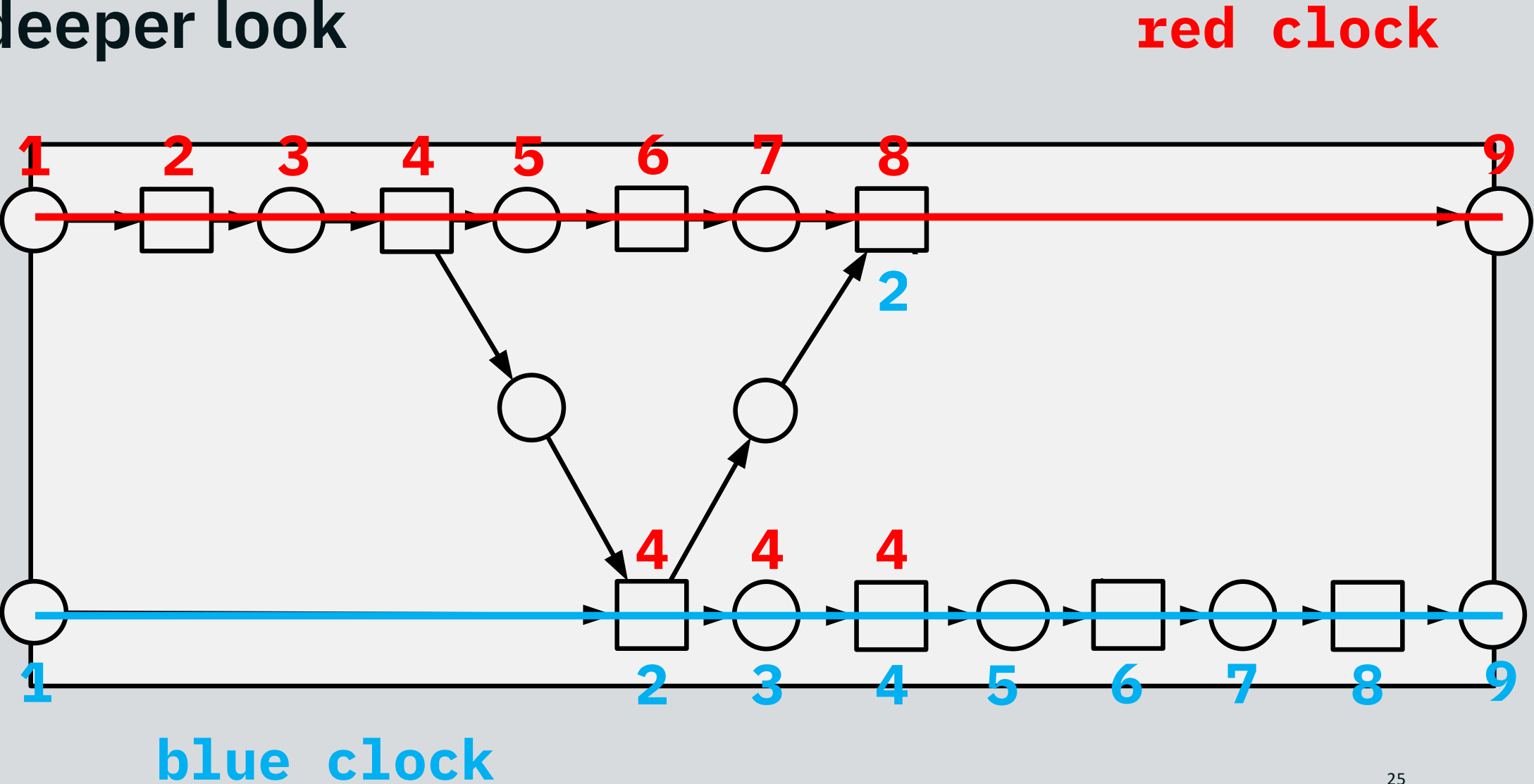
# red clock



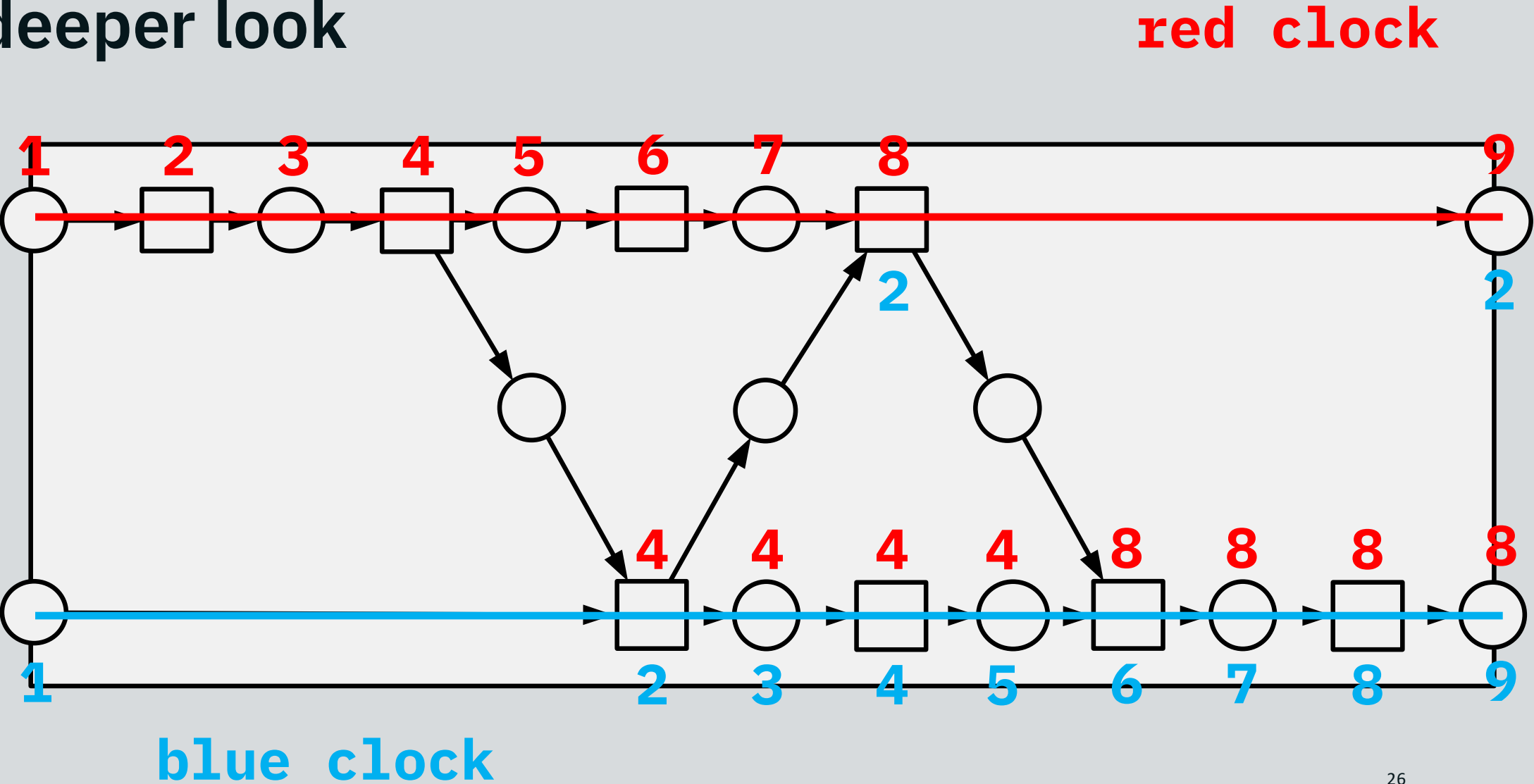
# blue clock



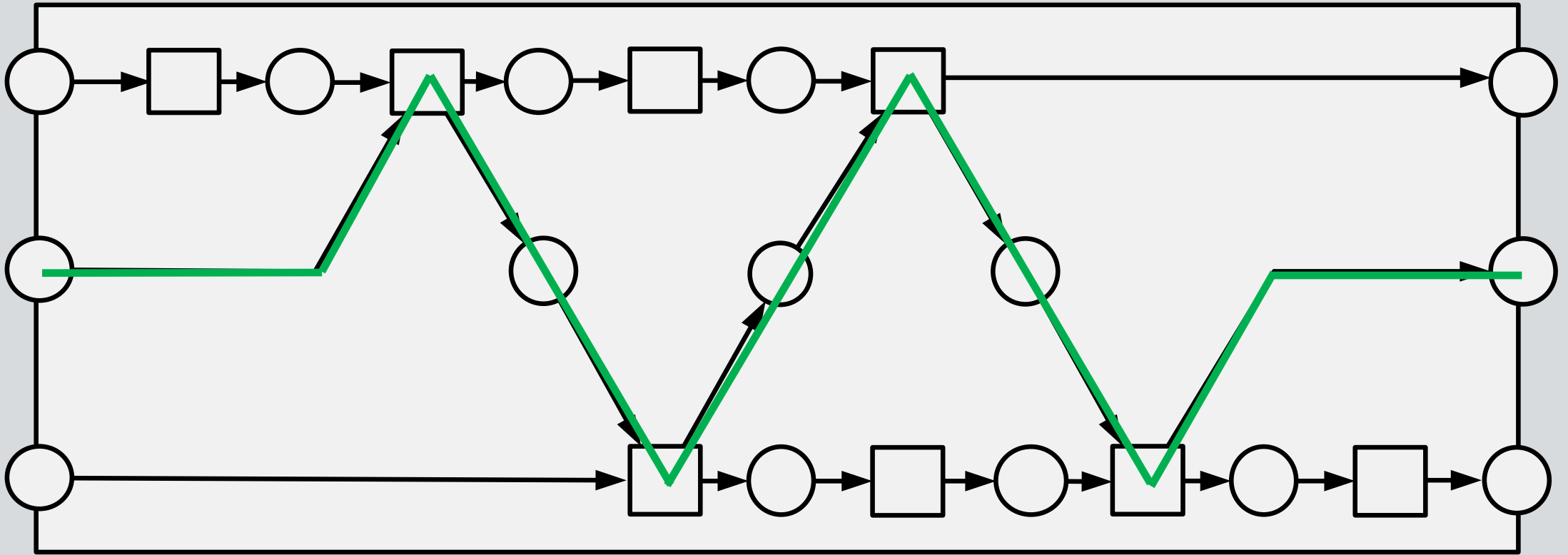
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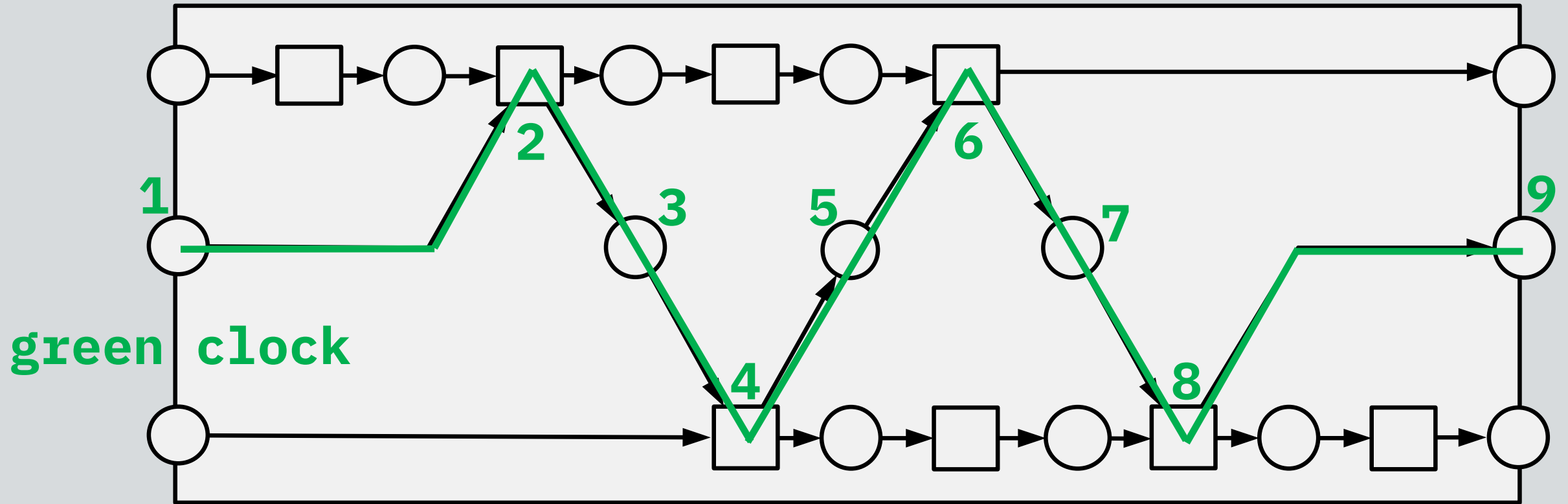
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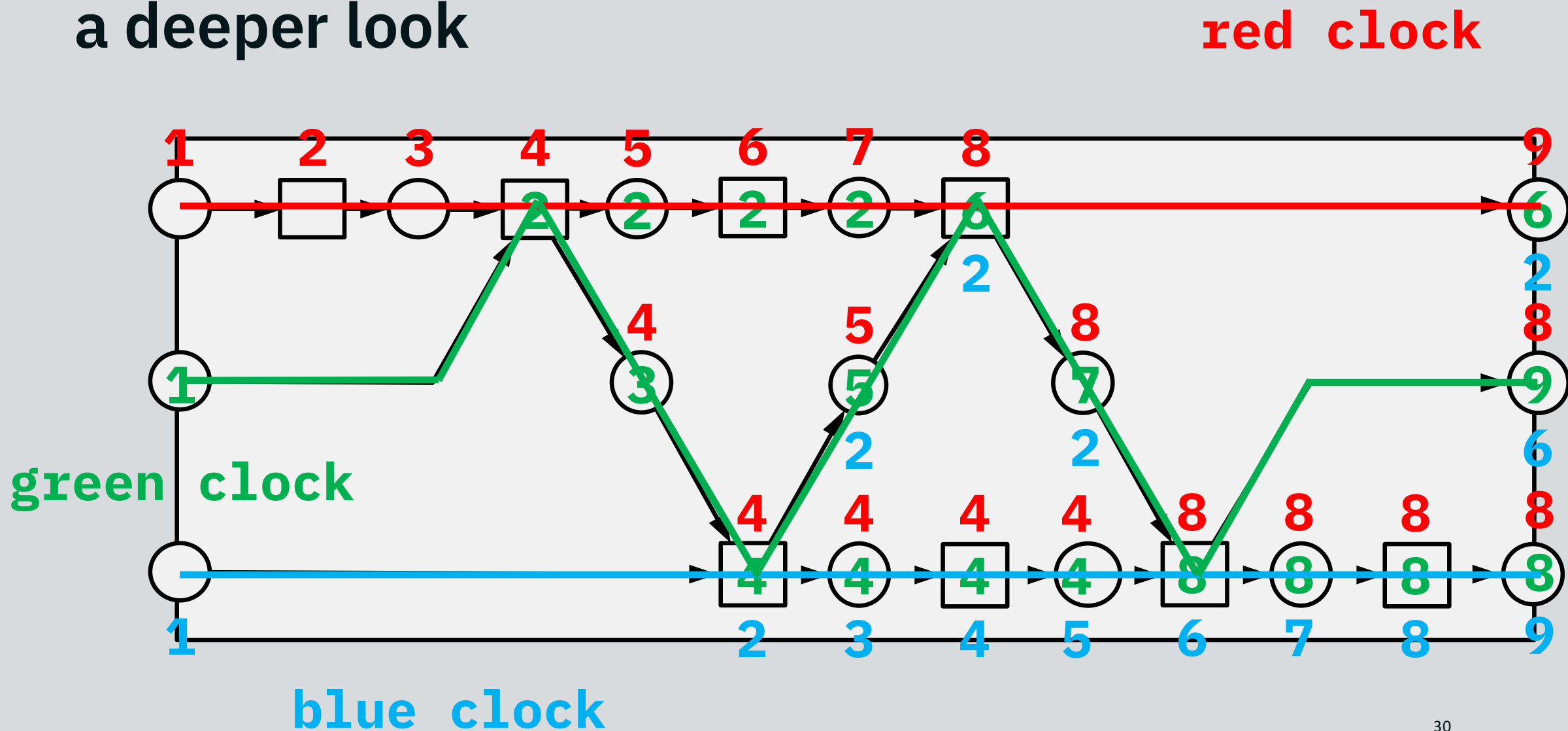
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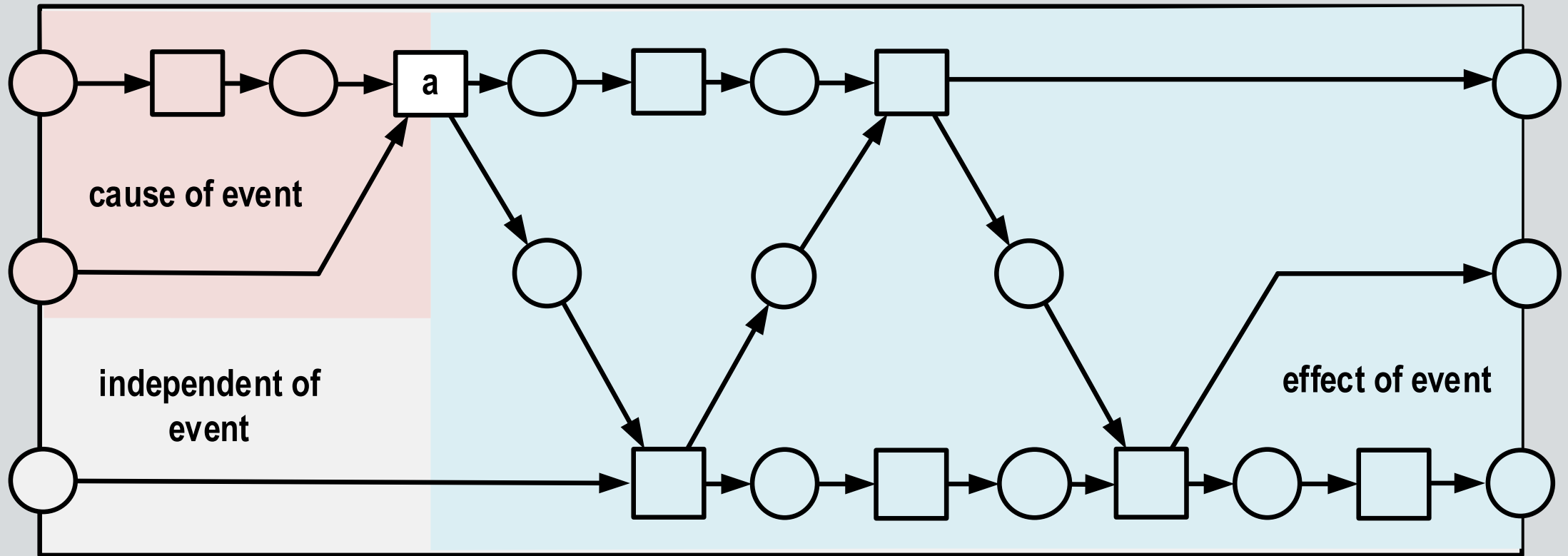
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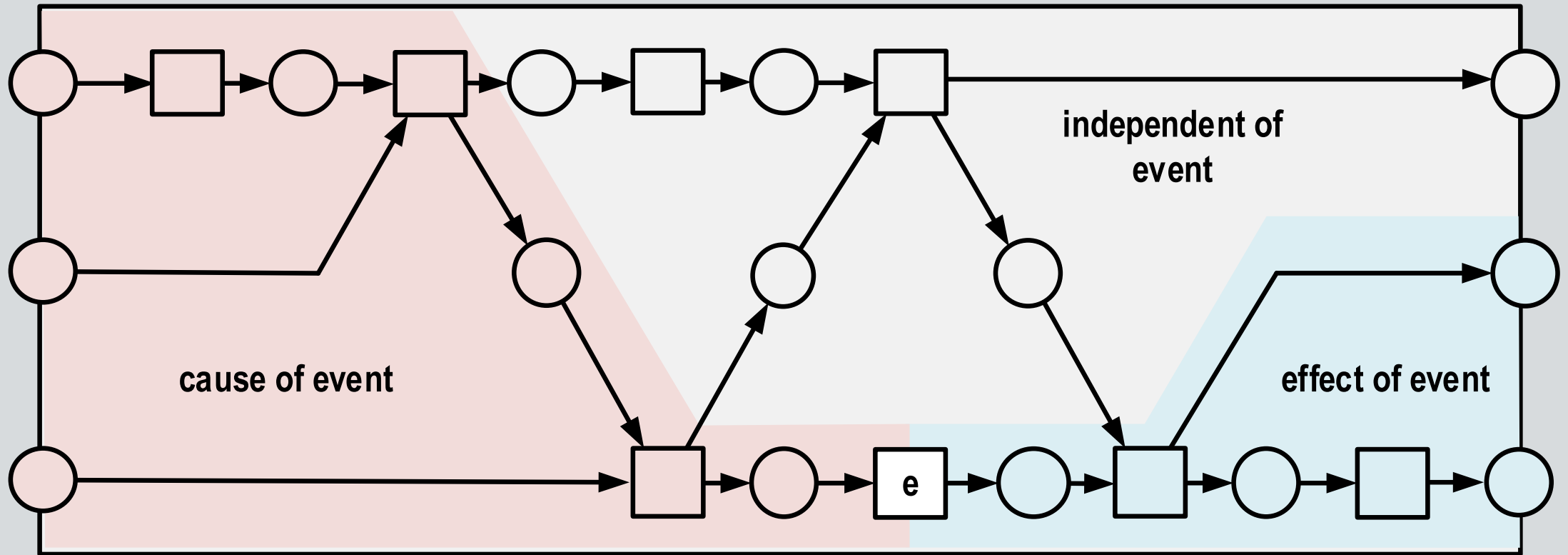
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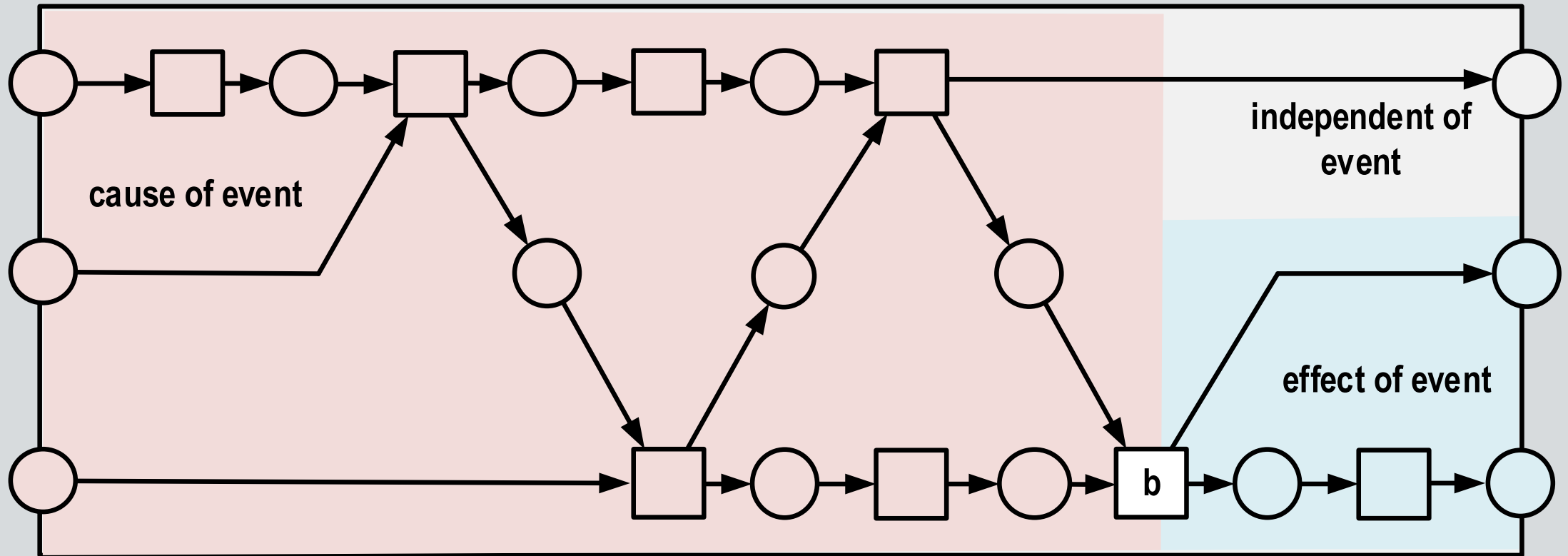
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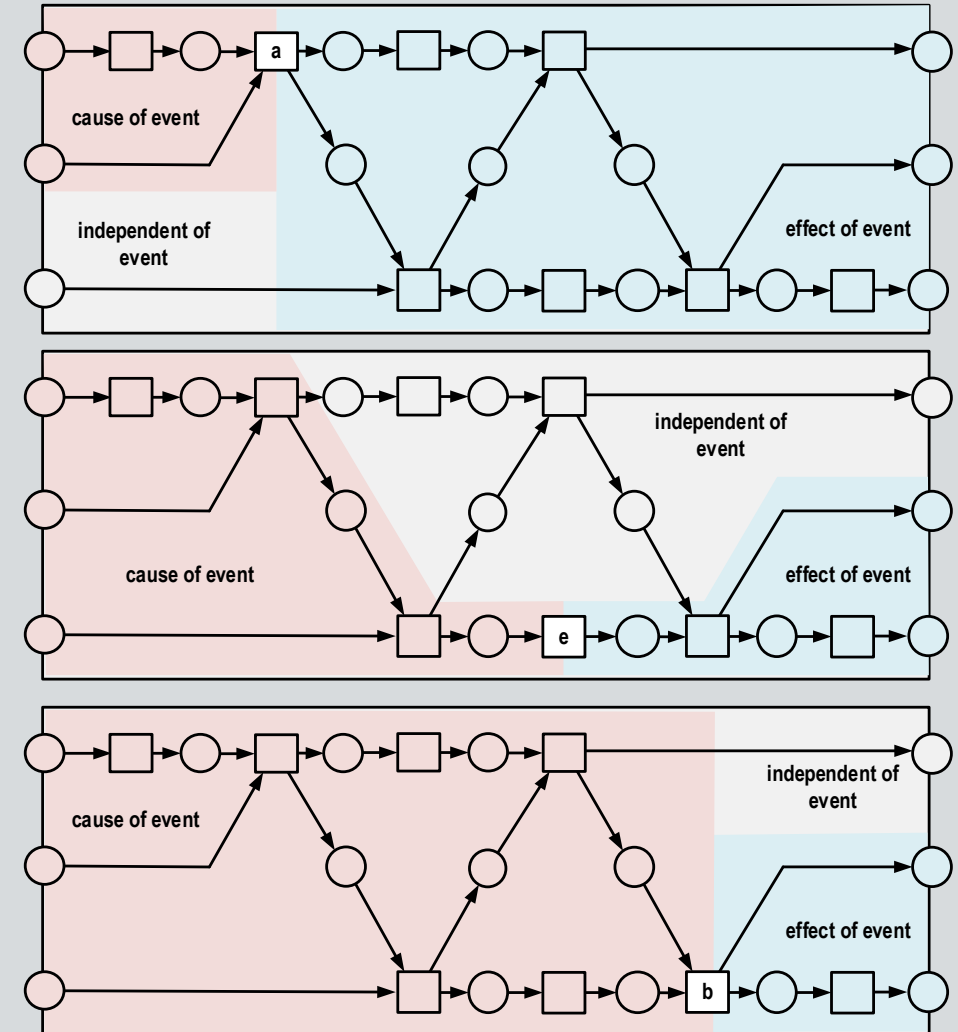




# Core of the digital world

## assumptions

1. discrete steps
2. discrete steps that partially order cause, effect, and independence
3. clock time follows causal time – and not vice versa



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# What is a market?

# “Marketing is King!”



Vol. 216, December 30, 1967

first be endorsed by the political committee and then by the General Assembly as a whole.

## Marketing is King

THE British engineering industry must give greater attention to marketing. This was the message delivered by the managing director of Massey Ferguson (UK), Mr J. W. Beith, in his lecture last week to the Institute of Mechanical Engineers.

Of the 14,992 engineering establishments in Britain, six hundred, or 4 per cent, account for two-thirds of the industry's total exports. An NEDC report in 1965 indicated that the probable rate of return on new investments in the engineering industry has been between 6 and 8 per cent during a period when the acceptable break-even rate was regarded as 15 per cent. Figures such as these, and the high import levels of foreign machine tools, indicate that some manufacturers fail to exploit in the market place the undoubted technical expertise which they possess.

Marketing, Mr Beith declared, should be the paramount activity in a company's operations, and must antedate and determine even the discovery in the research laboratories. If a product is to be tailored to its market, the whole strategy of a firm must be oriented towards the complex of research and planning activities which constitute marketing. Market research includes studies of such factors as the political and economic influences on a market, the demographic trends, the distribution of incomes and expenditures, and the likely appeal of alternative products. These findings form the basis for market planning, the function of which is to specify the product which will most profitably meet the situation described by market research. Market planning defines the physical characteristics of the product, its price, utility and styling; only then can design and manufacture begin, and any afterthoughts will be increasingly expensive. The goal of market planning is to strike the best balance between minimizing unit production costs and maximizing market appeal.

"The future of large sectors of engineering production," Mr Beith said, "will be influenced by the impact of marketing on engineering firms, and by the changes which it will bring about within those firms." The increasing importance of marketing is likely to favour the large firm against the small and to lead to fewer and larger firms. But perhaps the greatest change as firms become more market oriented, Mr Beith suggests, is that engineers will be expected to work within the parameters of the marketing approach and to think in terms not of the product itself but of its marketability.

programme was well over the horizon, perhaps as much as 25 years ahead. As for the proposal, put to him by Mr David Price, that he transfer Culham from the Atomic Energy Authority to the Science Research Council, he said that work on astrophysics at Culham was to be undertaken by the SRC, and that he was taking Mr Price's proposals seriously.

## Sonic Booms

THE subject of sonic booms came up in both written and oral questions on December 19. The Minister of State for the Ministry of Technology, Mr Stonehouse, said that no decision had been made about restrictions to be placed on the speed of the Concorde airliner over inhabited areas. He estimated that the total market for the aircraft would be reduced to 65 per cent if a ban were to be imposed on the making of supersonic booms overland. Mr Stonehouse went on to say that he did not think it would be wise to start international discussions on supersonic flight over land. Britain, he said, was in touch with France and the United States and would co-ordinate with them in any decision. Nobody could be certain about the characteristics of the bang from Concorde until the aircraft was flying, but there was a great deal that could be learned, and was being learned, from the intensive tests carried out in the United States. In written replies to questions put to him by members, Mr Stonehouse said that the Ministry of Technology would shortly issue a statement about the July sonic boom tests. Thirteen local authorities had commented on various aspects of these tests.

## American Aircraft Imports

IN a written answer, Mr Stonehouse gave figures for the trade in aircraft and space products between Britain and the United States in the first ten months of this year. Britain imported £64,541,000 worth of aircraft, exporting £37,645,000 worth to the US. Mr Stonehouse thought that the export prospects of the aircraft industry would be enhanced as a result of devaluation. A Procurement Committee had been established under the British National Export Council and the Confederation of British Industries with the object of securing orders within the aerospace and avionics fields. (Written answer, December 20.)

## Civil Defence Warning System

LORD STONHAM, Minister of State, Home Office, in a debate in the House of Lords, gave details of the warning system which would be used to alert the civil population in the event of war. He claimed that the warning system was virtually instantaneous and nation-wide. There were two types of warning signal. The first was a siren similar to that used in the last war. The difference was that the system would now



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NATURE, VOL. 216, DECEMBER 30, 1967

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# Commercial break

Peter Fettke · Wolfgang Reisig

## Understanding the Digital World

Modeling with HERAKLIT

This book fills a serious gap by providing a conceptual framework for understanding the digital world. This world contains large, heterogeneous systems that have to manage dynamic behavior as well as static items and data. Obviously, new, *digital methods* are needed to deal with the challenges of the digital world.

This book introduces such a method with HERAKLIT, an intuitively simple, albeit powerful framework for modeling, communicating, and analyzing computer-integrated systems. It integrates proven methods for composing modules, describing behavior with local cause and effect, and digitally representing real- and imagined-world items, resulting in a comprehensive, expressive, concerted, technically simple, digital modeling method.

This book is structured according to three HERAKLIT pillars, starting in Part I with the central HERAKLIT concept of modules, in particular their composition and refinement. Part II covers the second pillar of HERAKLIT, dynamics, focusing on modules that describe aspects of behavior. Part III focuses on static aspects. In particular, real- and imagined-world items and their symbolic representation are carefully distinguished and related. Together, these three pillars are consolidated in Part IV, integrating all concepts into a powerful formal framework. The book concludes in Part V with a more comprehensive case study of a typical retail business, recommendations on how to start modeling with HERAKLIT, and useful graphical conventions for the graphical representation of HERAKLIT models.

HERAKLIT covers the range from the first informal structuring ideas for a computer-integrated system, through the specification of (business) processes, the contributions of people, organizations, and mechanical devices, up to the construction of software. The book is therefore written for students in areas related to system modeling, system design, and system engineering, as well as for professionals in these fields.

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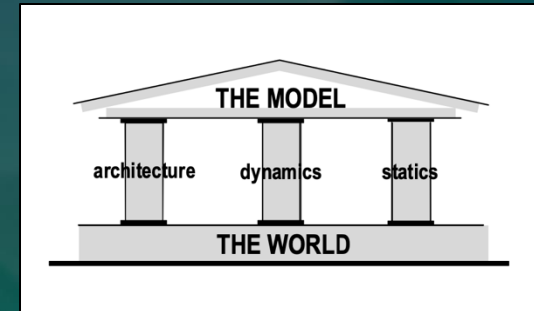


Understanding the Digital World

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Wolfgang Reisig

## Understanding the Digital World

Modeling with HERAKLIT



 Springer

# What is a market?

“A market is a group of economic agents who are trading a good or service plus the rules and arrangements for trading.”\*



Daron Acemoglu  
(Nobel Prize in Economics in 2024)



# What is a market?

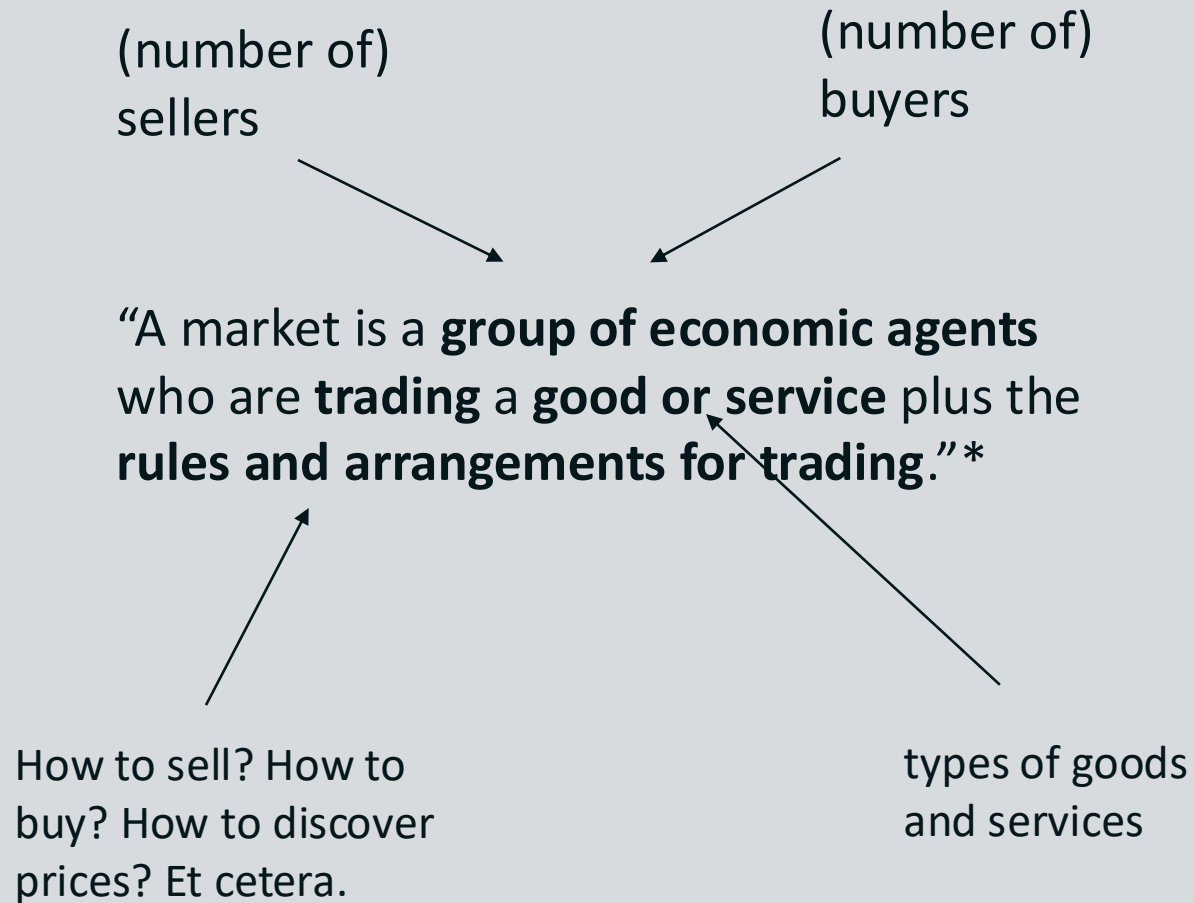
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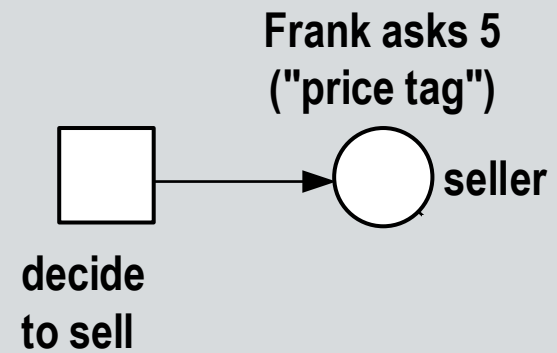




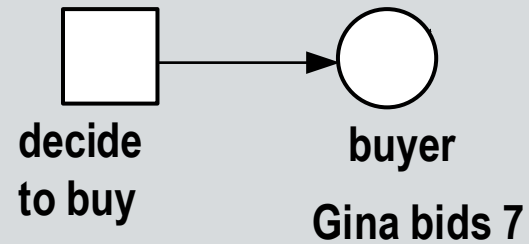
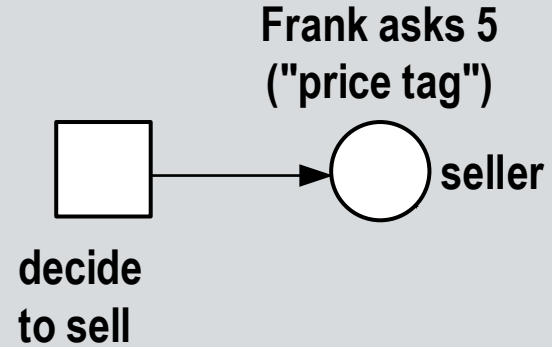




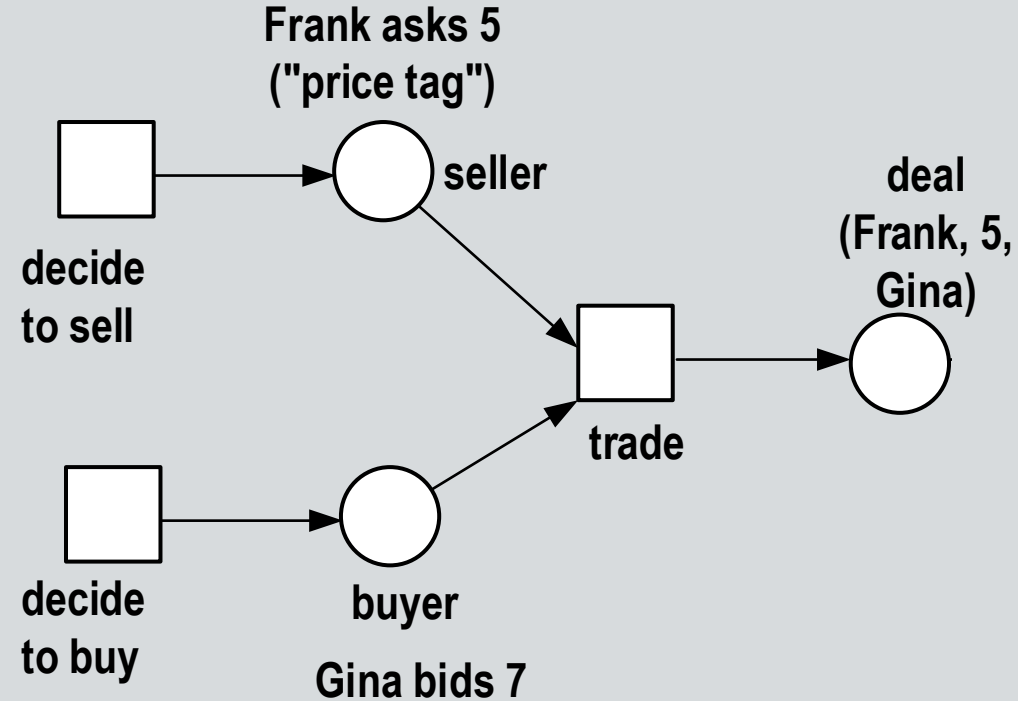
# Supermarket: price tag with fix price



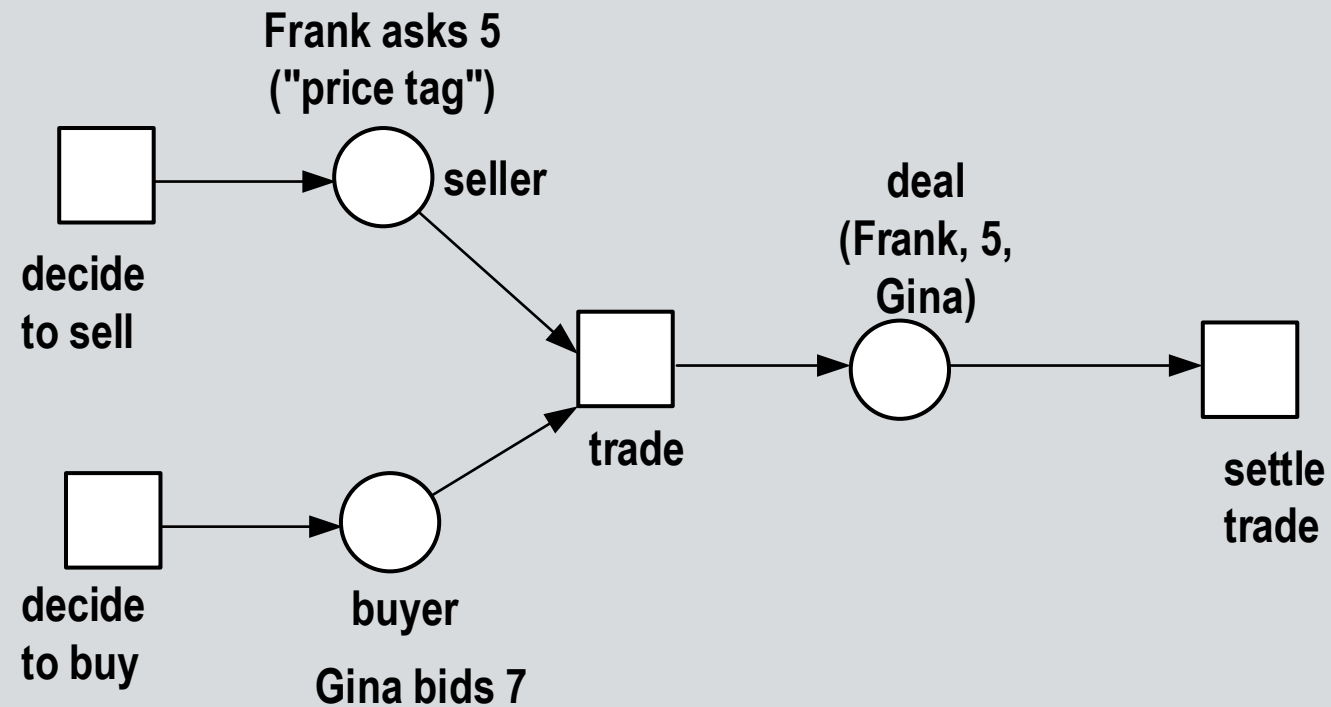
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# European Price Indication Directive

18. 3. 98

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Official Journal of the European Communities

L 80/27

## DIRECTIVE 98/6/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 16 February 1998

on consumer protection in the indication of the prices of products offered to consumers

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 129a(2) thereof,

Having regard to the proposal from the Commission <sup>(1)</sup>,

Having regard to the opinion of the Economic and Social Committee <sup>(2)</sup>,

Acting in accordance with the procedure laid down in Article 189b of the Treaty <sup>(3)</sup>, in the light of the joint text approved by the Conciliation Committee on 9 December 1997,

(1) Whereas transparent operation of the market and correct information is of benefit to consumer protection and healthy competition between enterprises and products;

(2) Whereas consumers must be guaranteed a high level of protection; whereas the Community should contribute thereto by specific action which supports and supplements the policy pursued by the Member States regarding precise, transparent and unambiguous information for consumers on the prices of products offered to them;

(3) Whereas the Council Resolution of 14 April 1975 on a preliminary programme of the European Economic Community for a consumer protection and information policy <sup>(4)</sup> and the Council Resolution of 19 May 1981 on a second programme of the European Economic Community for a consumer protection and information policy <sup>(5)</sup> provide for the establishment of common principles for indicating prices;

(4) Whereas these principles have been established by Directive 79/581/EEC concerning the indication of prices of certain foodstuffs <sup>(6)</sup> and Directive 88/314/EEC concerning the indication of prices of non-food products <sup>(7)</sup>;

(5) Whereas the link between indication of the unit price of products and their pre-packaging in pre-established quantities or capacities corresponding to the values of the ranges adopted at Community level has proved overly complex to apply; whereas it is thus necessary to abandon this link in favour of a new simplified mechanism and in the interest of the consumer, without prejudice to the rules governing packaging standardisation;

(6) Whereas the obligation to indicate the selling price and the unit price contributes substantially to improving consumer information, as this is the easiest way to enable consumers to evaluate and compare the price of products in an optimum manner and hence to make informed choices on the basis of simple comparisons;

(7) Whereas, therefore, there should be a general obligation to indicate both the selling price and the unit price for all products except for products sold in bulk, where the selling price cannot be determined until the consumer indicates how much of the product is required;

(8) Whereas it is necessary to take into account the fact that certain products are customarily sold in quantities different from one kilogramme, one litre, one metre, one square metre or one cubic metre; whereas it is thus appropriate to allow Member States to authorise that the unit price refer to a different single unit of quantity, taking into account the nature of the product and the quantities in which it is customarily sold in the Member State concerned;

(9) Whereas the obligation to indicate the unit price may entail an excessive burden for certain small retail businesses under certain circumstances; whereas Member States should therefore be allowed to refrain from applying this obligation during an appropriate transitional period;

<sup>(1)</sup> OJ C 260, 5. 10. 1995, p. 5 and

OJ C 249, 27. 8. 1996, p. 2.

<sup>(2)</sup> OJ C 82, 19. 3. 1996, p. 32.

<sup>(3)</sup> Opinion of the European Parliament of 18 April 1996 (OJ C 141, 13. 5. 1996, p. 191). Council Common Position of 27 September 1996 (OJ C 333, 7. 11. 1996, p. 7) and Decision of the European Parliament of 18 February 1997 (OJ C 85, 17. 3. 1997, p. 26). Decision of the European Parliament of 16 December 1997 and Decision of the Council of 18 December 1997.

<sup>(4)</sup> OJ C 92, 25. 4. 1975, p. 1.

<sup>(5)</sup> OJ C 133, 3. 6. 1981, p. 1.

<sup>(6)</sup> OJ L 158, 26. 6. 1979, p. 19. Directive as last amended by Directive 95/58/EC (OJ L 299, 12. 12. 1995, p. 11).

<sup>(7)</sup> OJ L 142, 9. 6. 1988, p. 19. Directive as last amended by Directive 95/58/EC (OJ L 299, 12. 12. 1995, p. 11).

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(9) Whereas the obligation to indicate the unit price may entail an excessive burden for certain small retail businesses under certain circumstances; whereas Member States should therefore be allowed to refrain from applying this obligation during an appropriate transitional period;

(1) OJ C 260, 5. 10. 1995, p. 5 and OJ C 249, 27. 8. 1996, p. 2.

(2) OJ C 82, 19. 3. 1996, p. 32.

(3) Opinion of the European Parliament of 18 April 1996 (OJ C 141, 13. 5. 1996, p. 191). Council Common Position of 27 September 1996 (OJ C 333, 7. 11. 1996, p. 7) and Decision of the European Parliament of 18 February 1997 (OJ C 85, 17. 3. 1997, p. 26). Decision of the European Parliament of 16 December 1997 and Decision of the Council of 18 December 1997.

(4) OJ C 92, 25. 4. 1975, p. 1.

(5) OJ C 133, 3. 6. 1981, p. 1.

(6) OJ L 158, 26. 6. 1979, p. 19. Directive as last amended by Directive 95/58/EC (OJ L 299, 12. 12. 1995, p. 11).

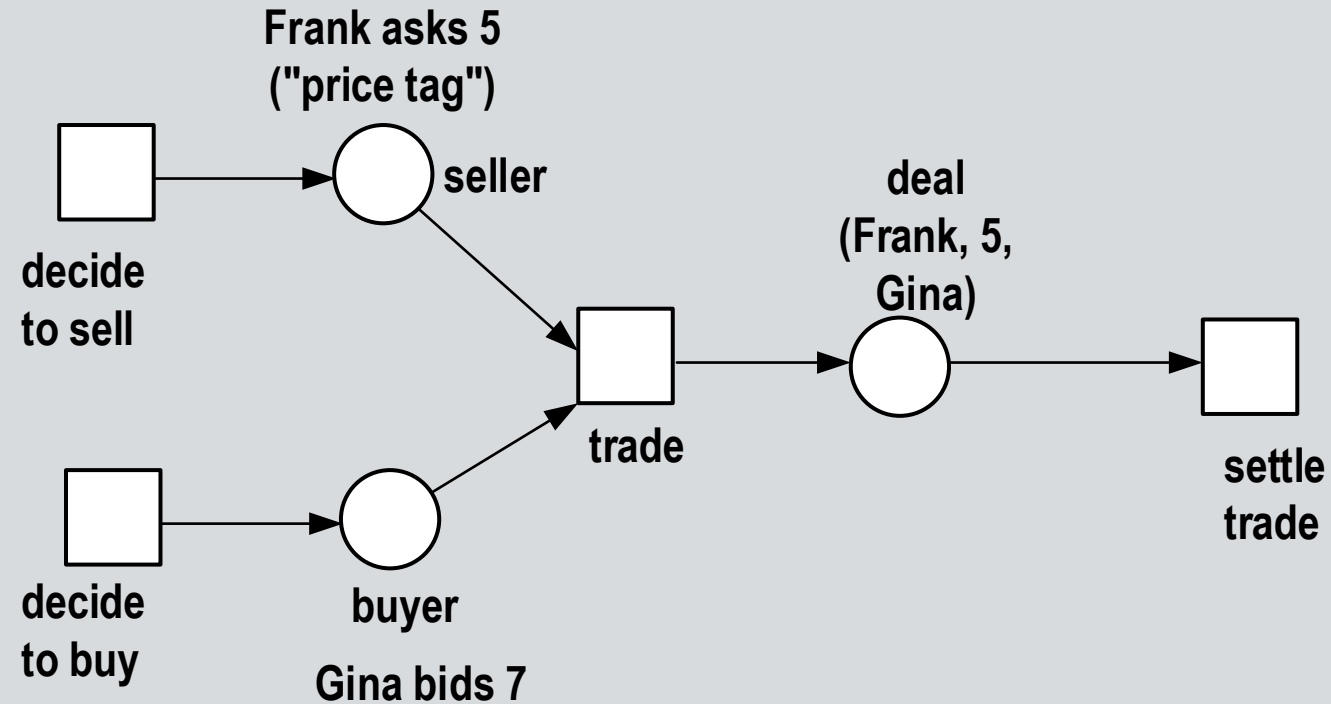
(7) OJ L 142, 9. 6. 1988, p. 19. Directive as last amended by Directive 95/58/EC (OJ L 299, 12. 12. 1995, p. 11).

“The selling price must be unambiguous, easily identifiable and clearly legible.”

Source:

[https://commission.europa.eu/law/law-topic/consumer-protection-law/unfair-commercial-practices-and-price-indication/price-indication-directive\\_en](https://commission.europa.eu/law/law-topic/consumer-protection-law/unfair-commercial-practices-and-price-indication/price-indication-directive_en)

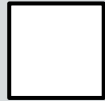
# Supermarket: price tag with fix price



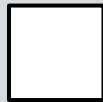




# Bazar: one seller and one buyer

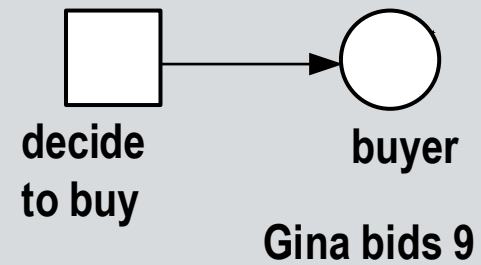
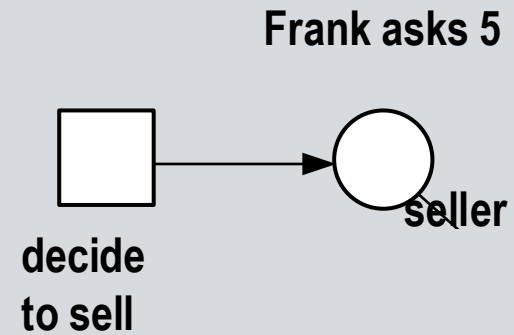


decide  
to sell

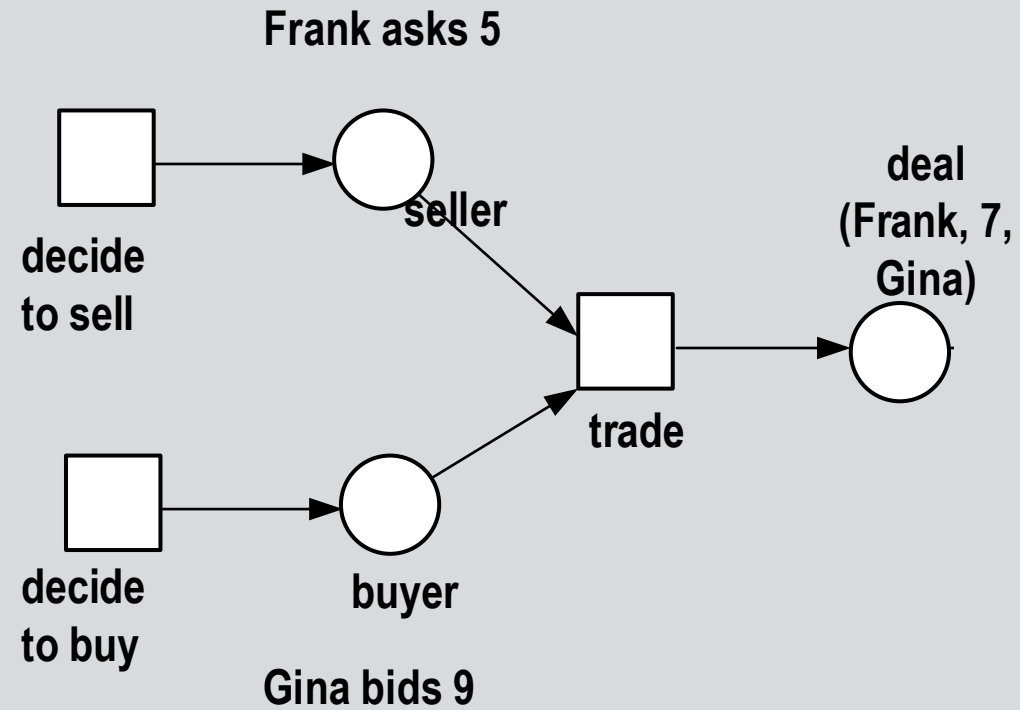


decide  
to buy

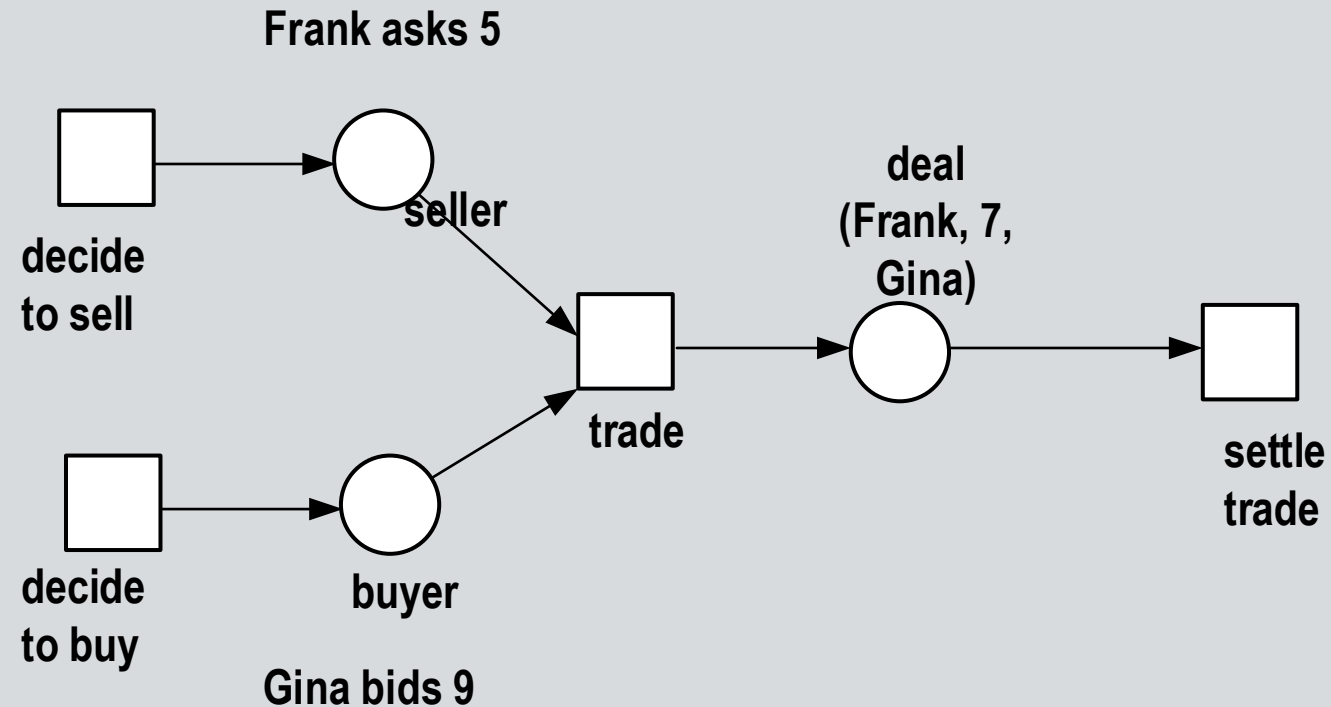
# Bazar: one seller and one buyer



# Bazar: one seller and one buyer

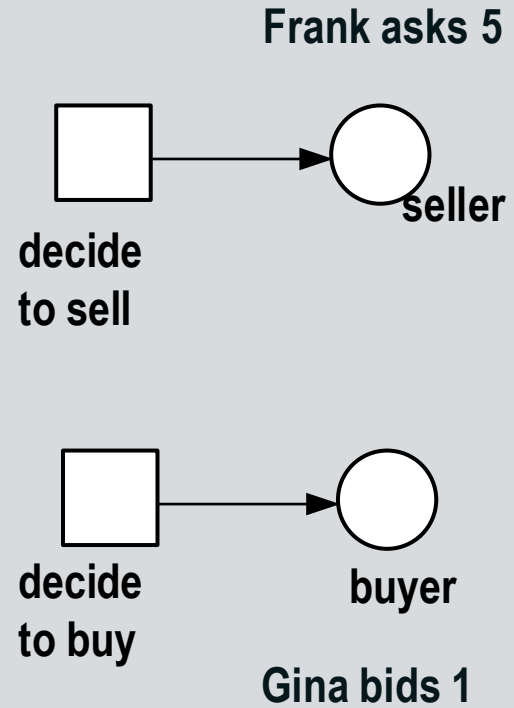


# Bazar: one seller and one buyer





# Bazar: one seller and one buyer but no deal

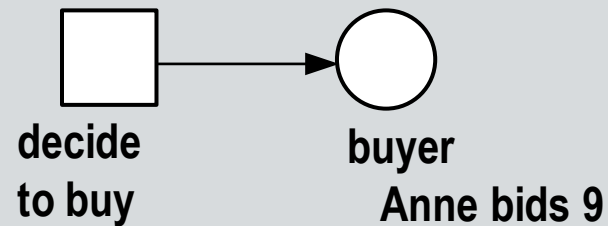
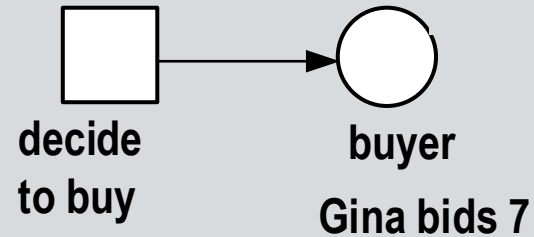
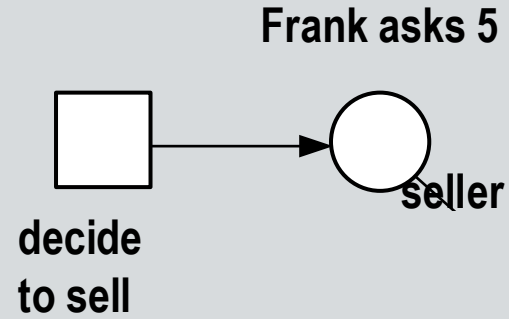




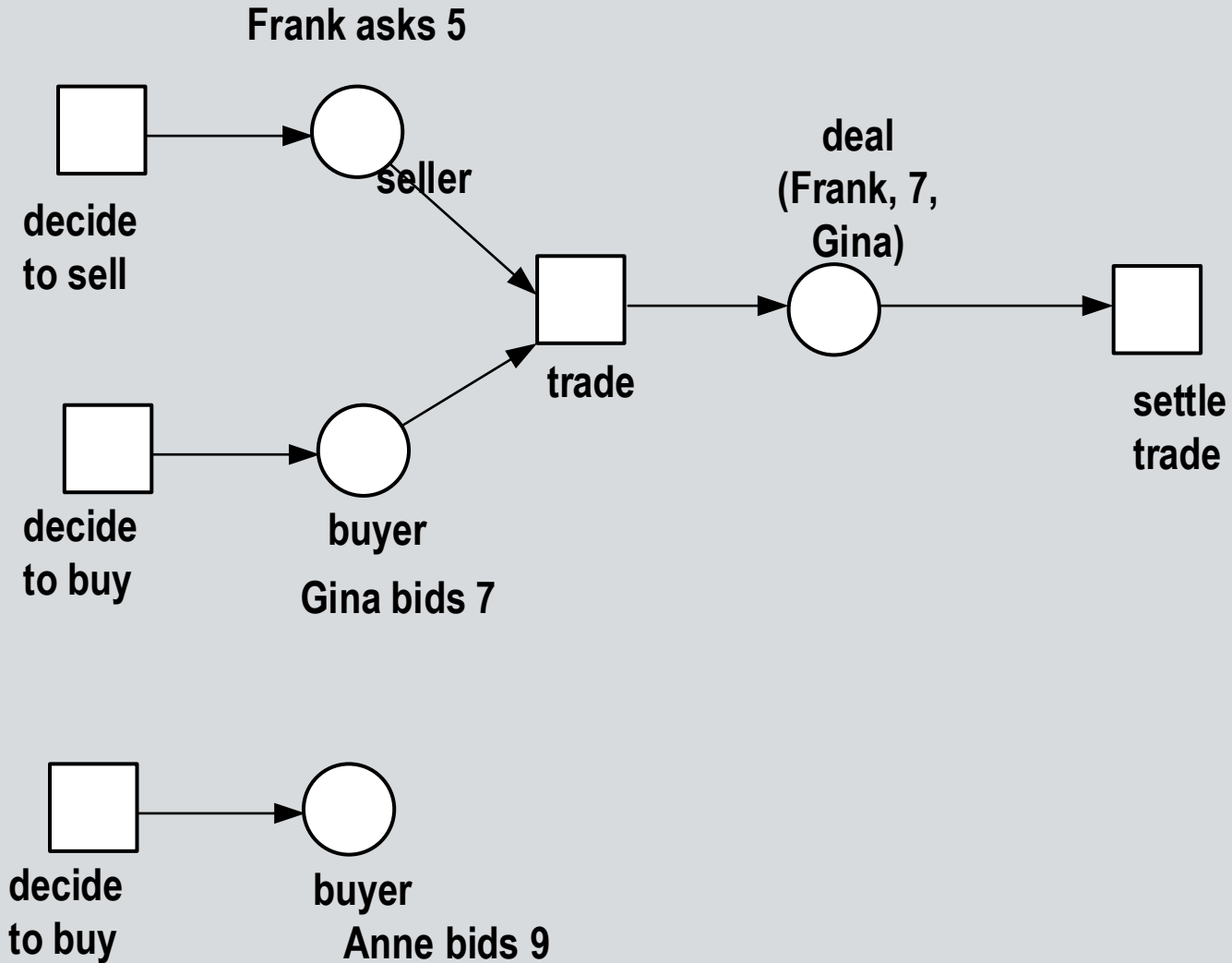




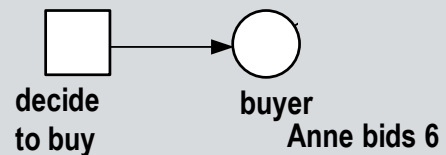
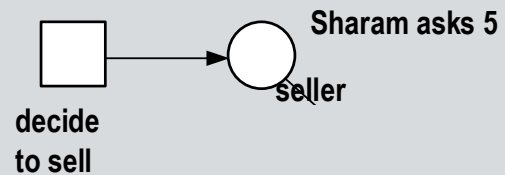
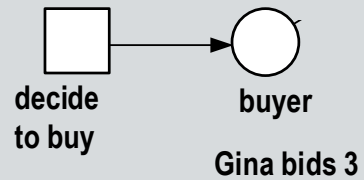
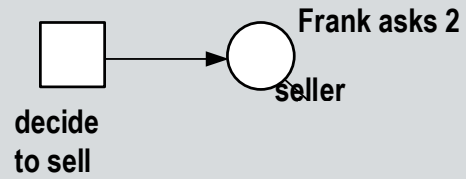
# Bazar: one seller and two buyers – better deal possible for seller



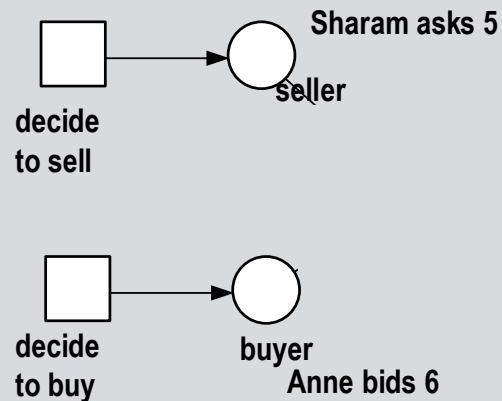
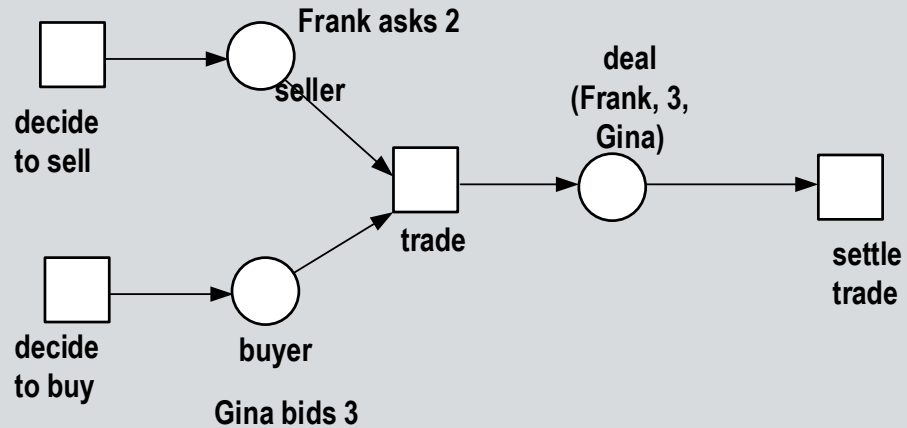
# Bazar: one seller and two buyers – better deal possible for seller



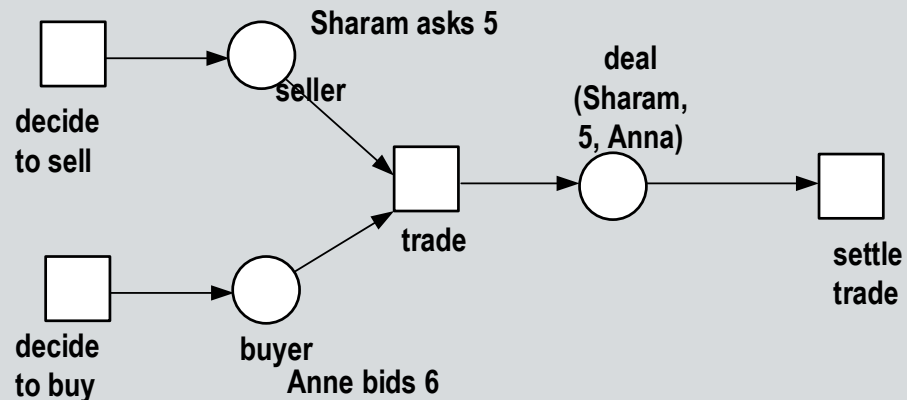
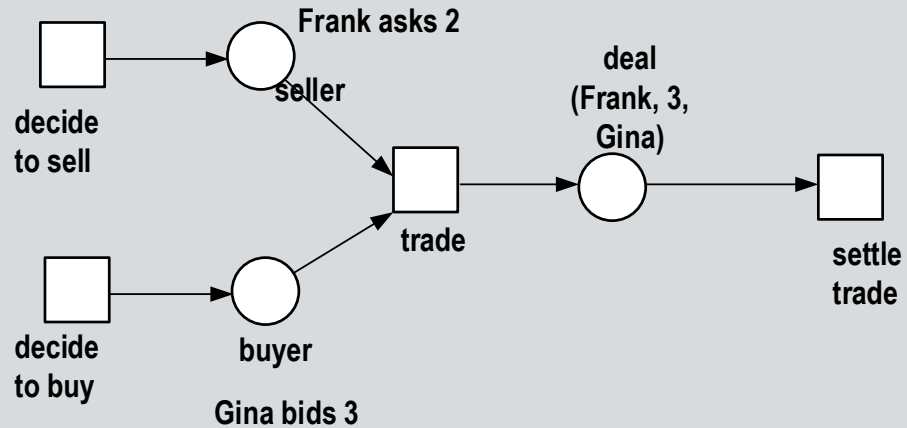
# Bazar: two sellers and two buyers with different prices for deals



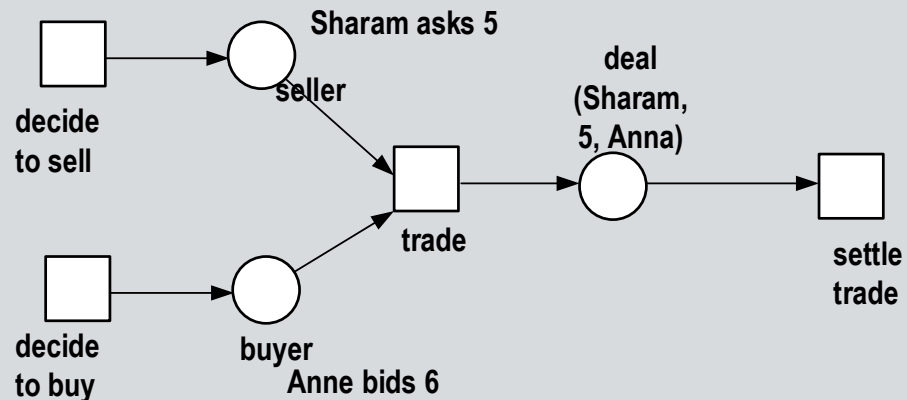
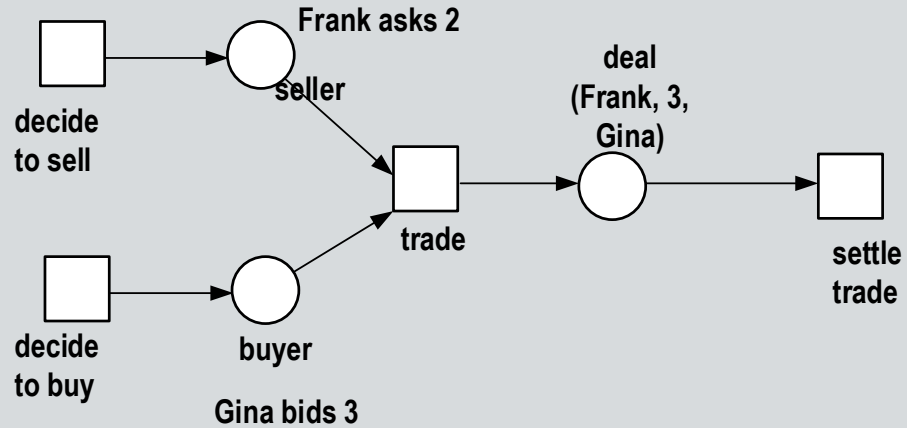
# Bazar: two sellers and two buyers with different prices for deals



# Bazar: two sellers and two buyers with different prices for deals

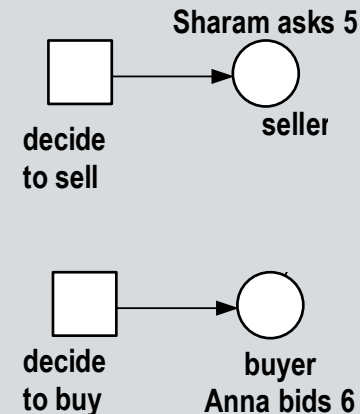
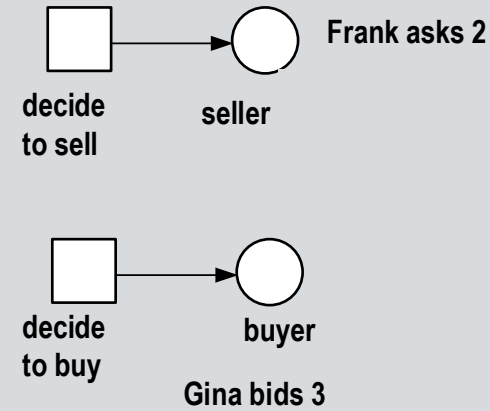
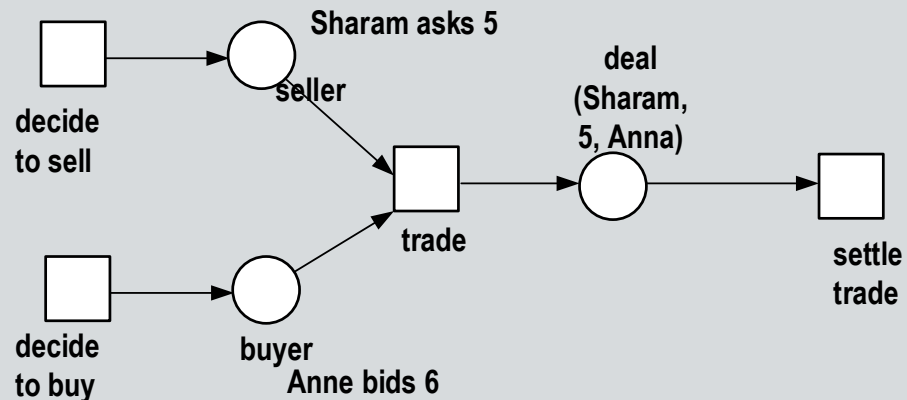
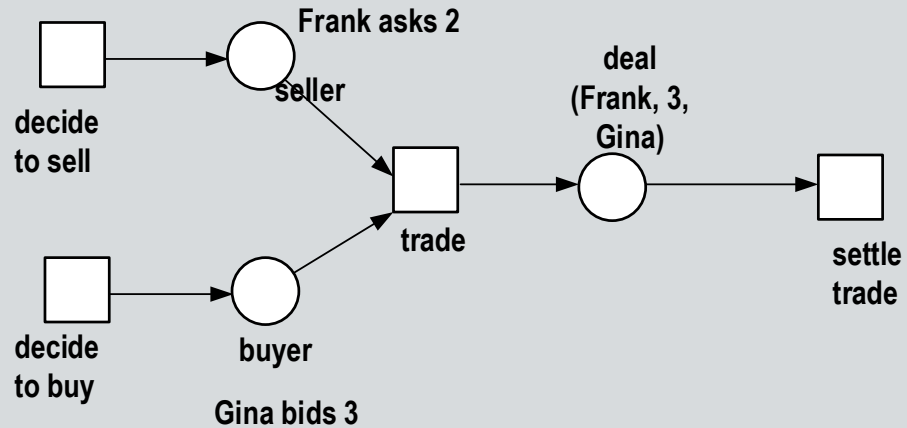


# Bazar: same sellers and same buyers, but different deals – lack of coordination

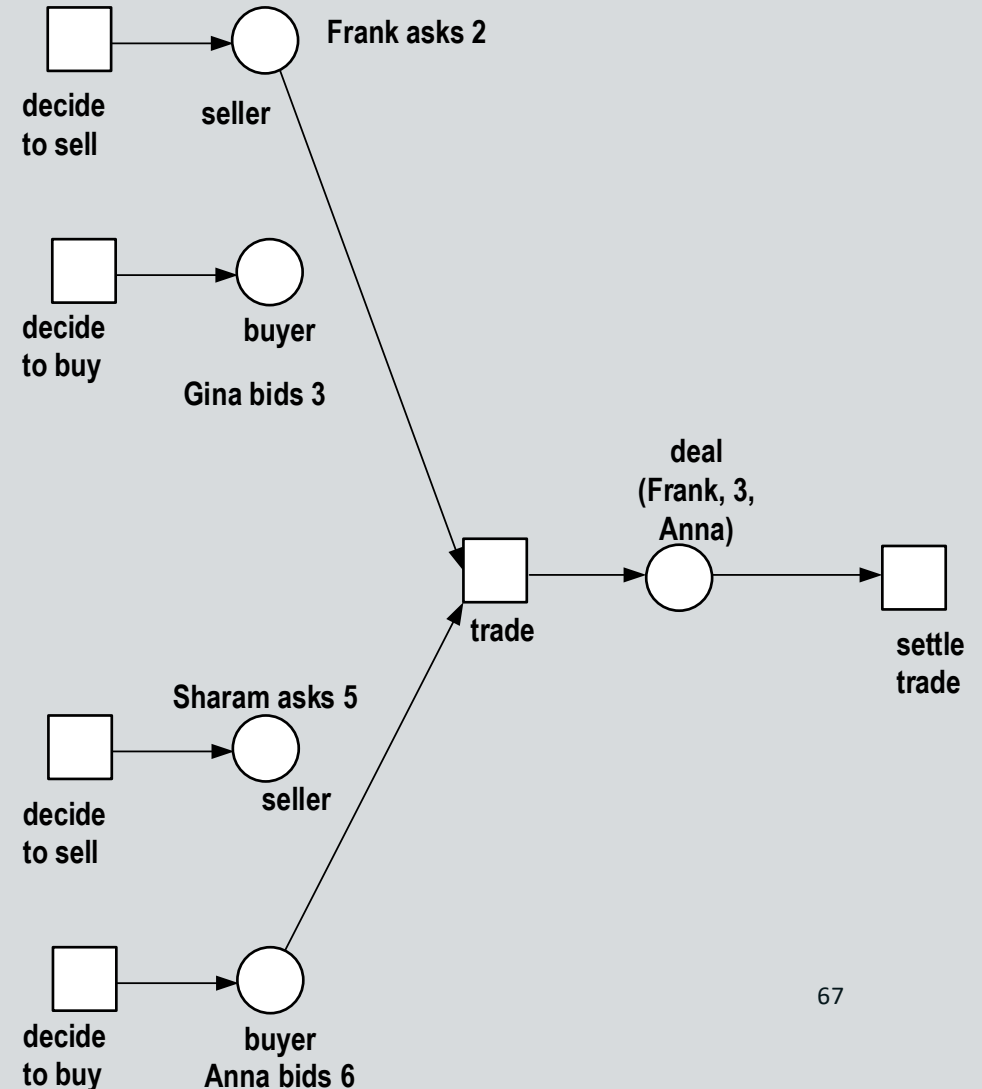
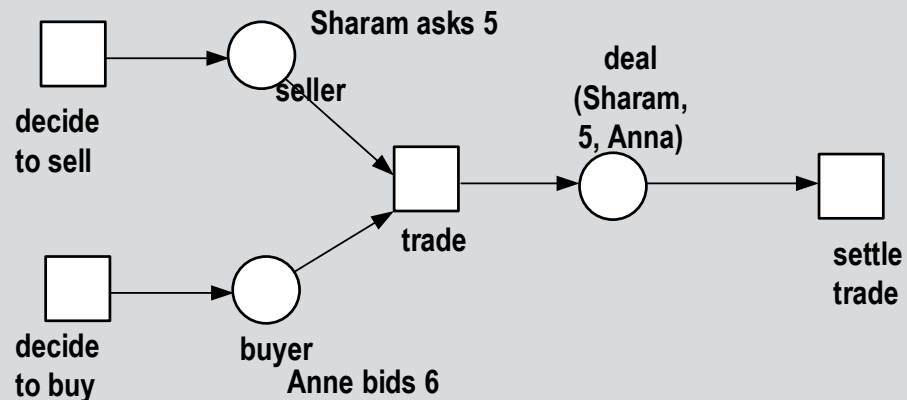
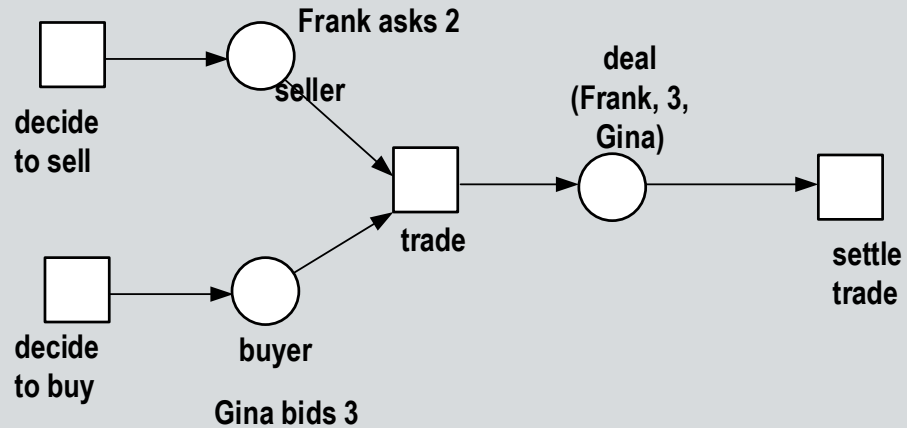




# Bazar: same sellers and same buyers, but different deals – lack of coordination



# Bazar: same sellers and same buyers, but different deals – lack of coordination





Sotheby's 1744

Sotheby's

Sotheby's

by's

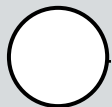
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Sotheby's

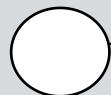
# Auction: one seller and one buyer

Frank asks 3

seller

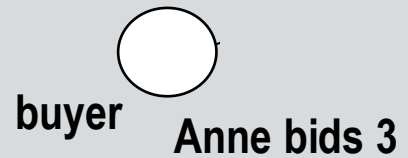
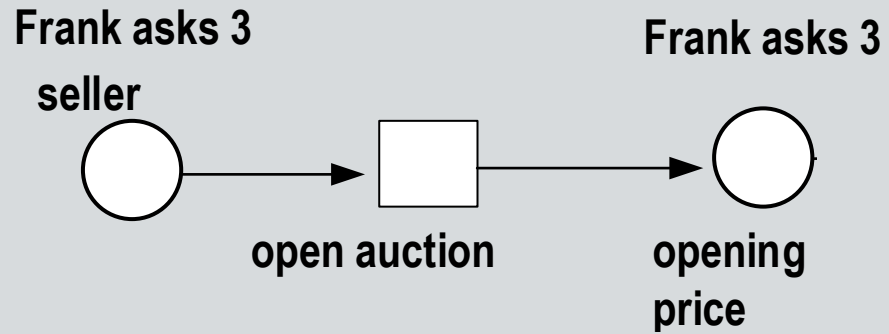


buyer

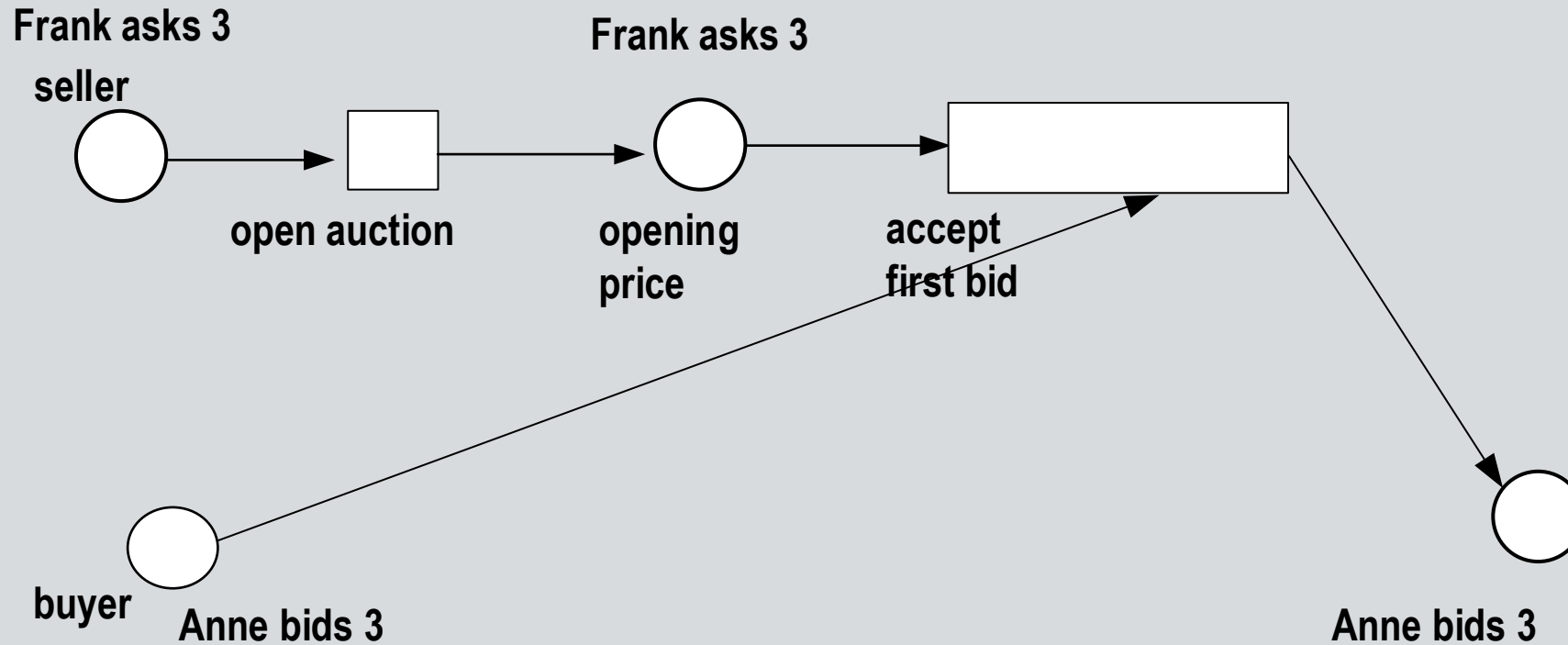


Anne bids 3

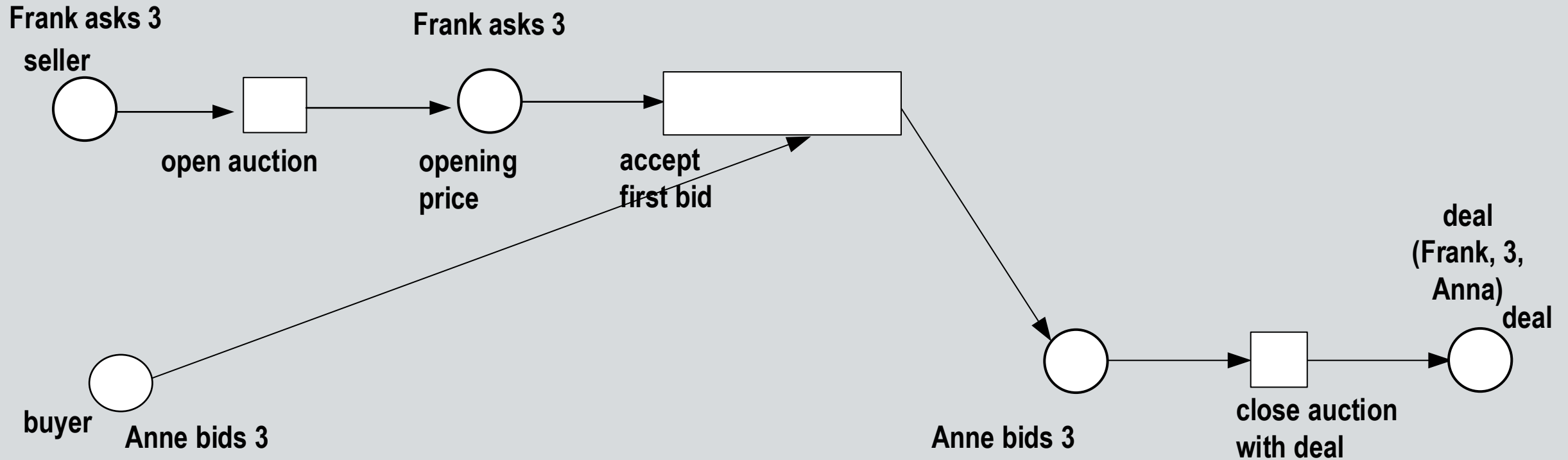
# Auction: one seller and one buyer



# Auction: one seller and one buyer



# Auction: one seller and one buyer



# Auction: one seller and two buyers

Frank asks 3

seller



buyer 1



Anne bids 3

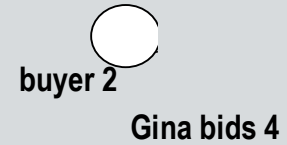
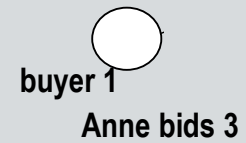
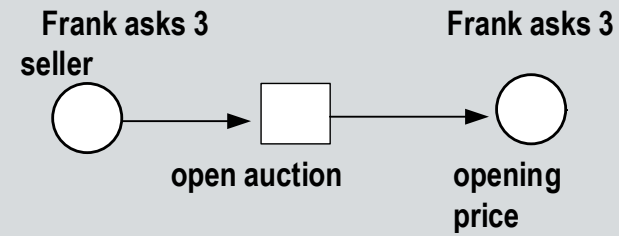
buyer 2



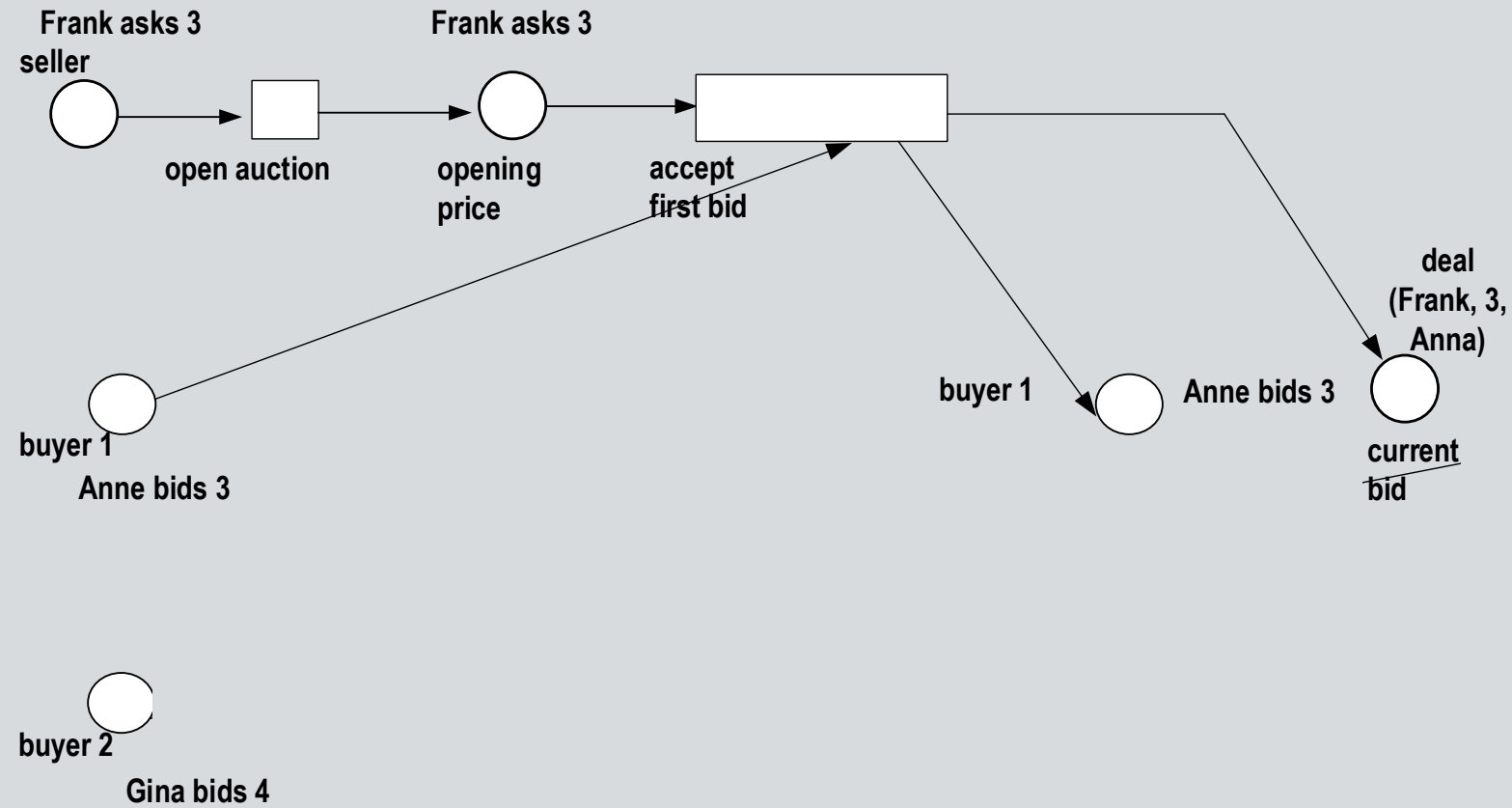
Gina bids 4



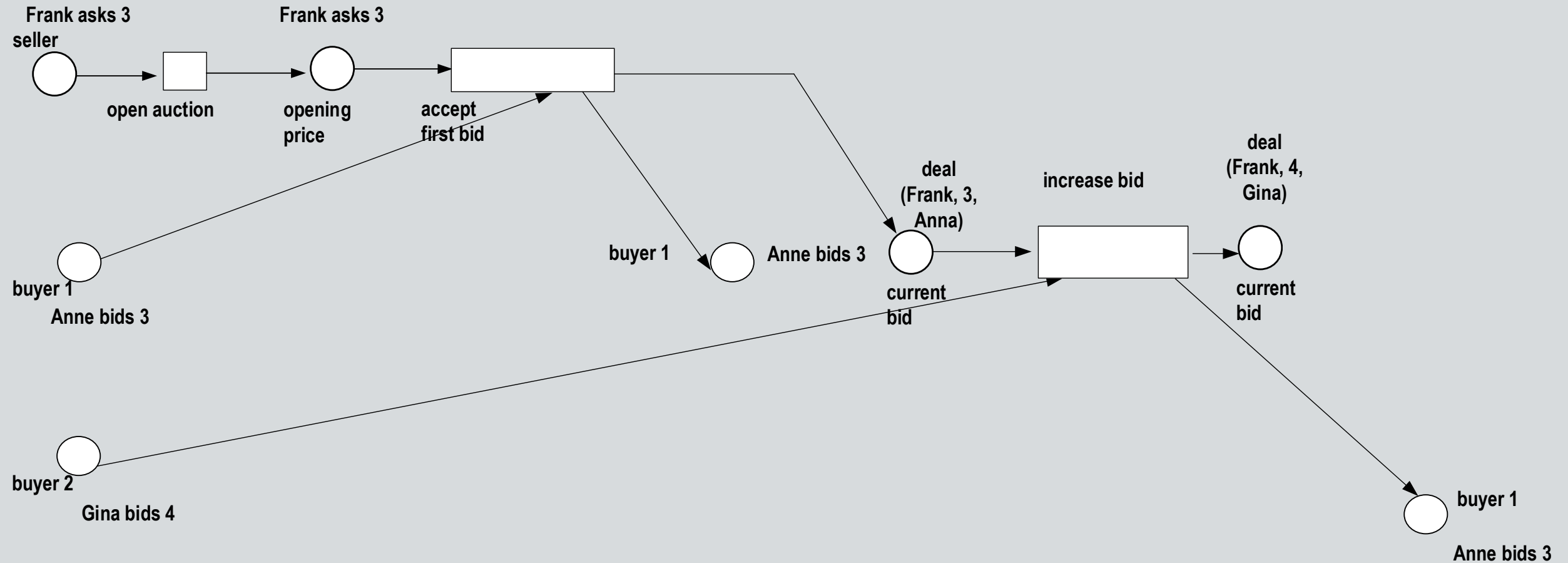
# Auction: one seller and two buyers



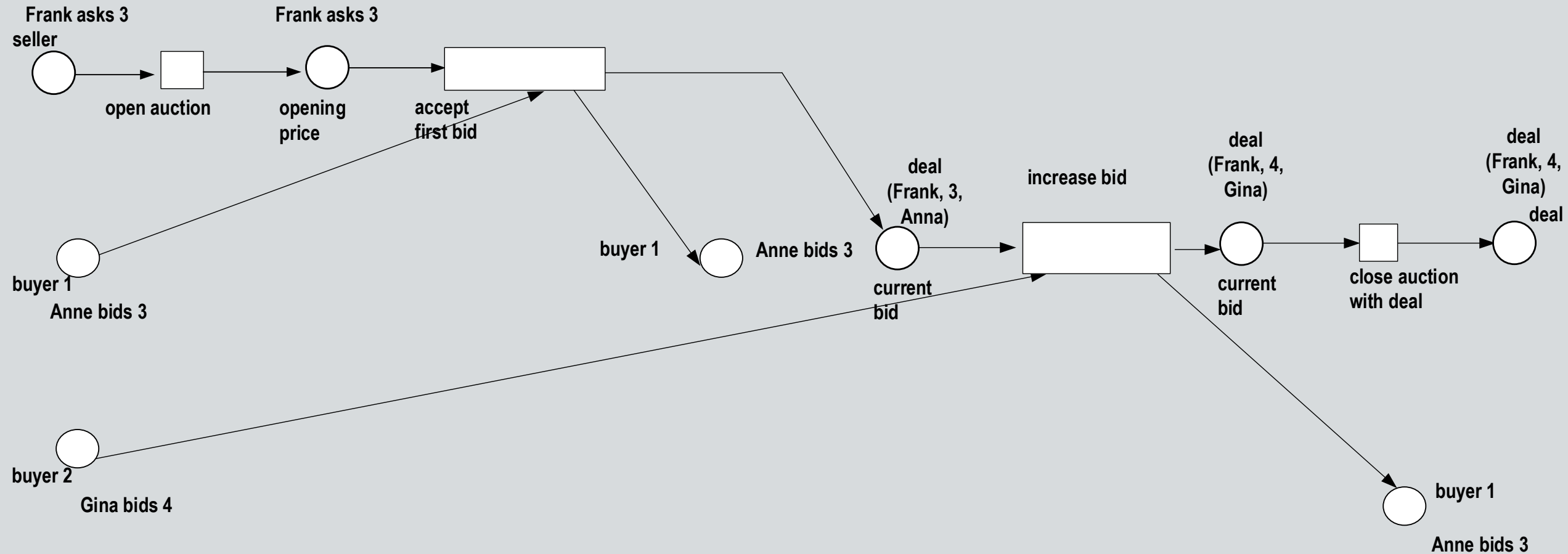
# Auction: one seller and two buyers



# Auction: one seller and two buyers



# Auction: one seller and two buyers









# Stock exchange (opening) auction: one seller and one buyer

Frank asks 3



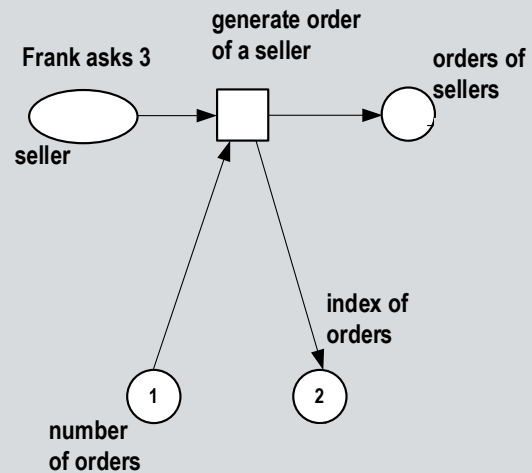
seller



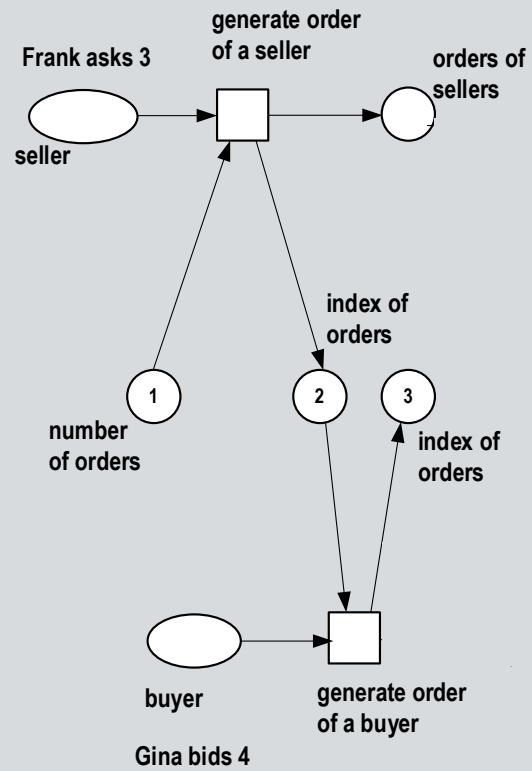
buyer

Gina bids 4

# Stock exchange (opening) auction: one seller and one buyer

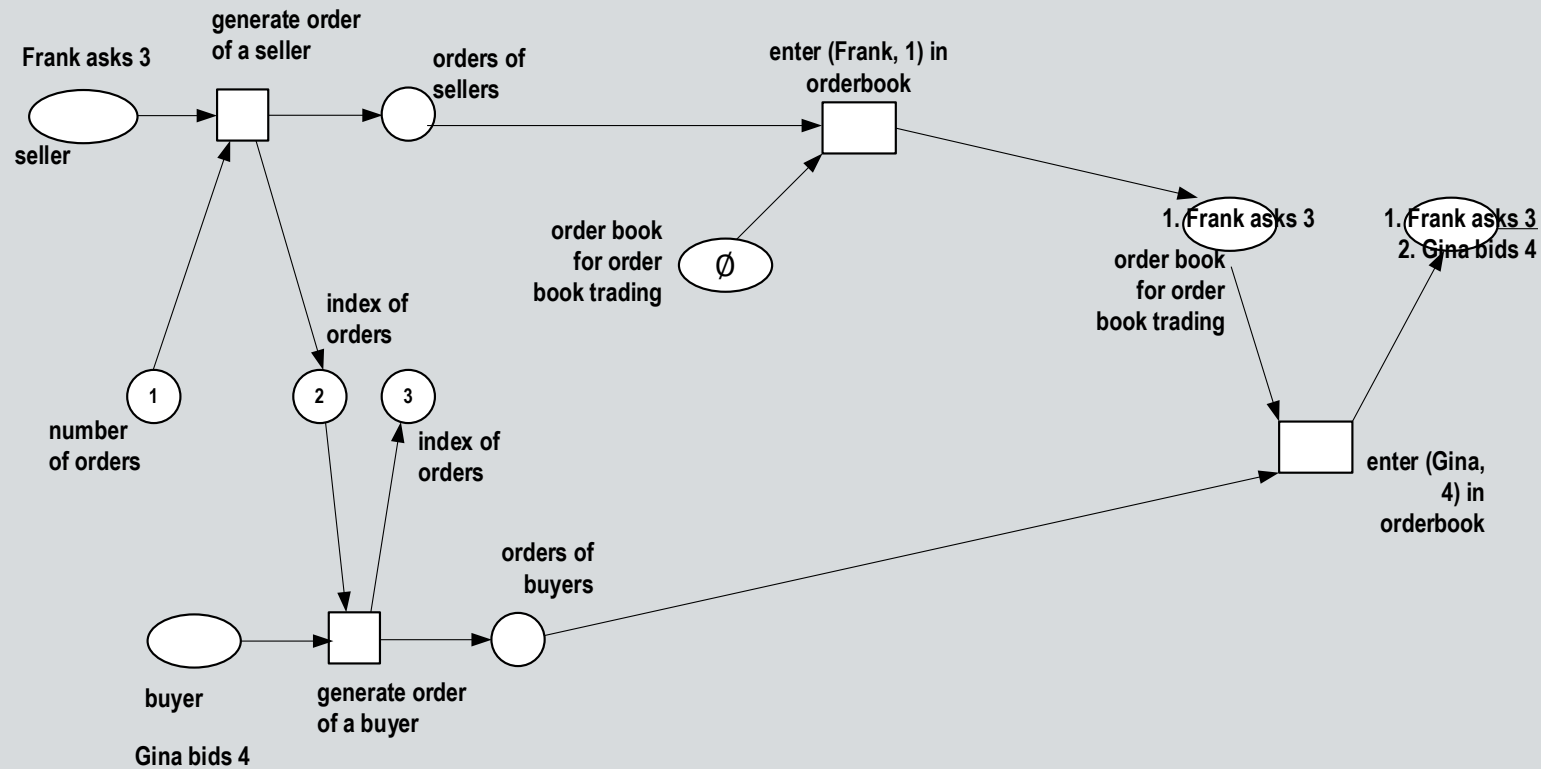


# Stock exchange (opening) auction: one seller and one buyer

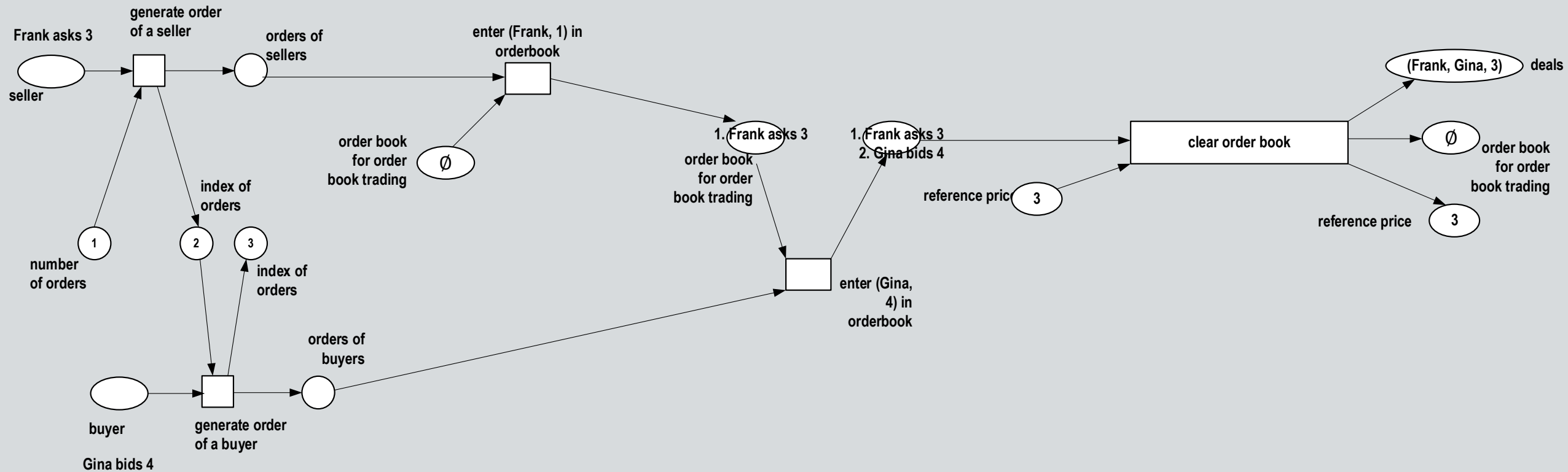




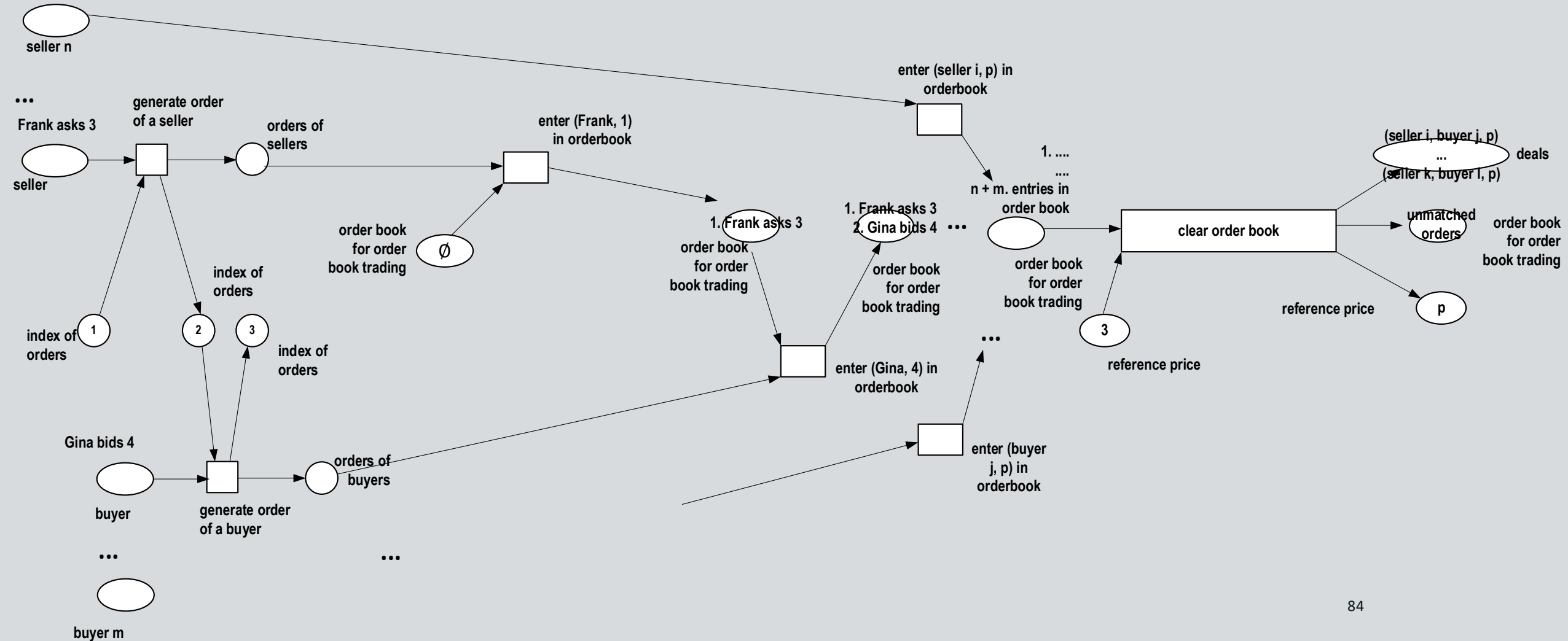
# Stock exchange (opening) auction: one seller and one buyer



# Stock exchange (opening) auction: one seller and one buyer



# Stock exchange (opening) auction: multiple sellers and multiple buyers



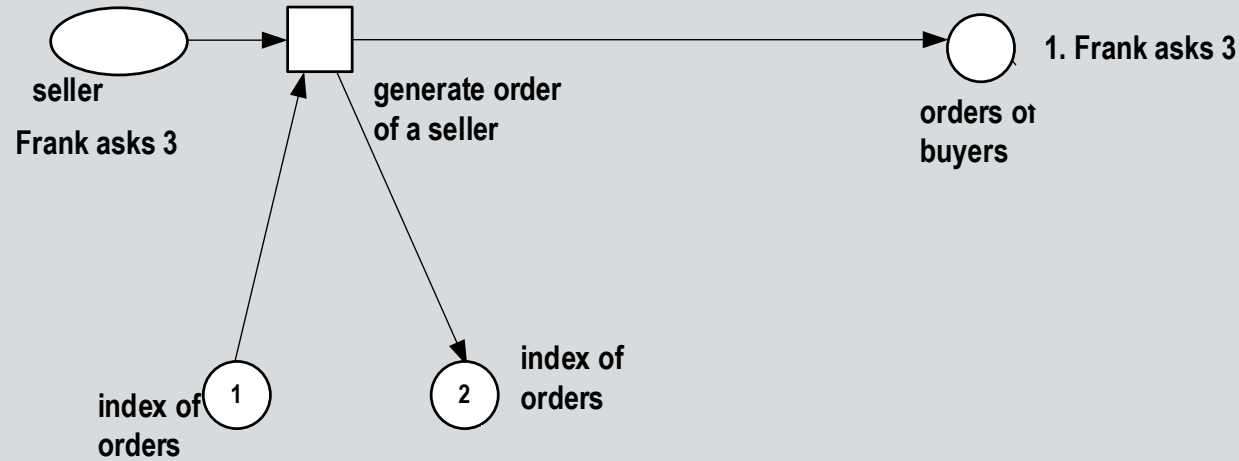
# Stock exchange: continuous trading: empty order book & direct match



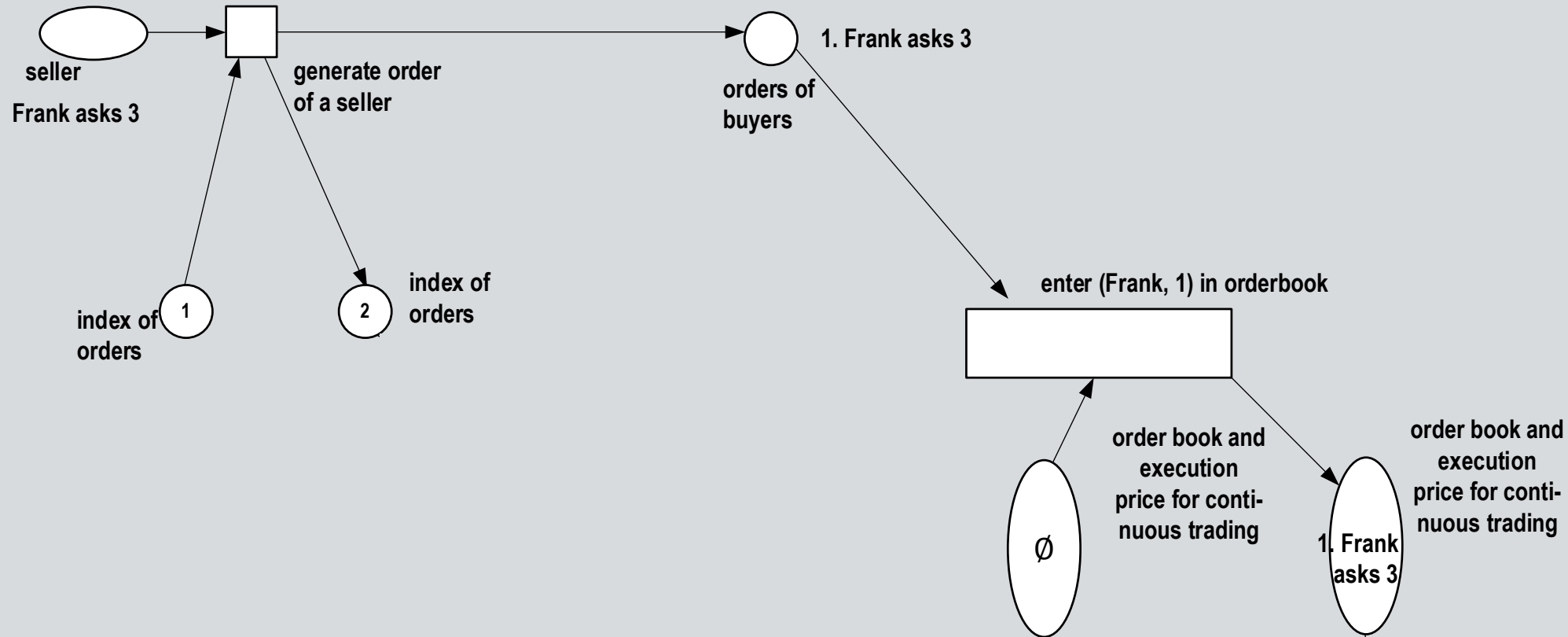
seller

Frank asks 3

# Stock exchange: continuous trading: empty order book & direct match

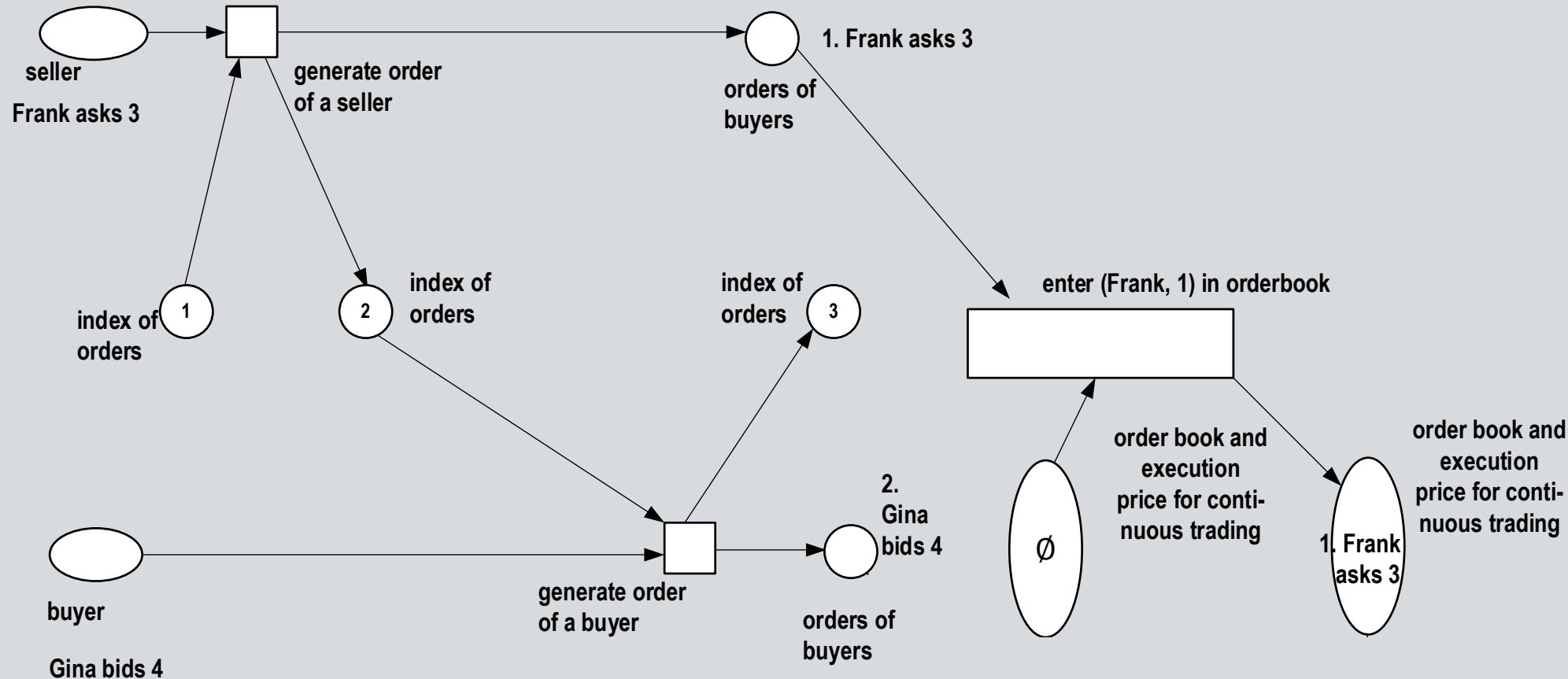


# Stock exchange: continuous trading: empty order book & direct match

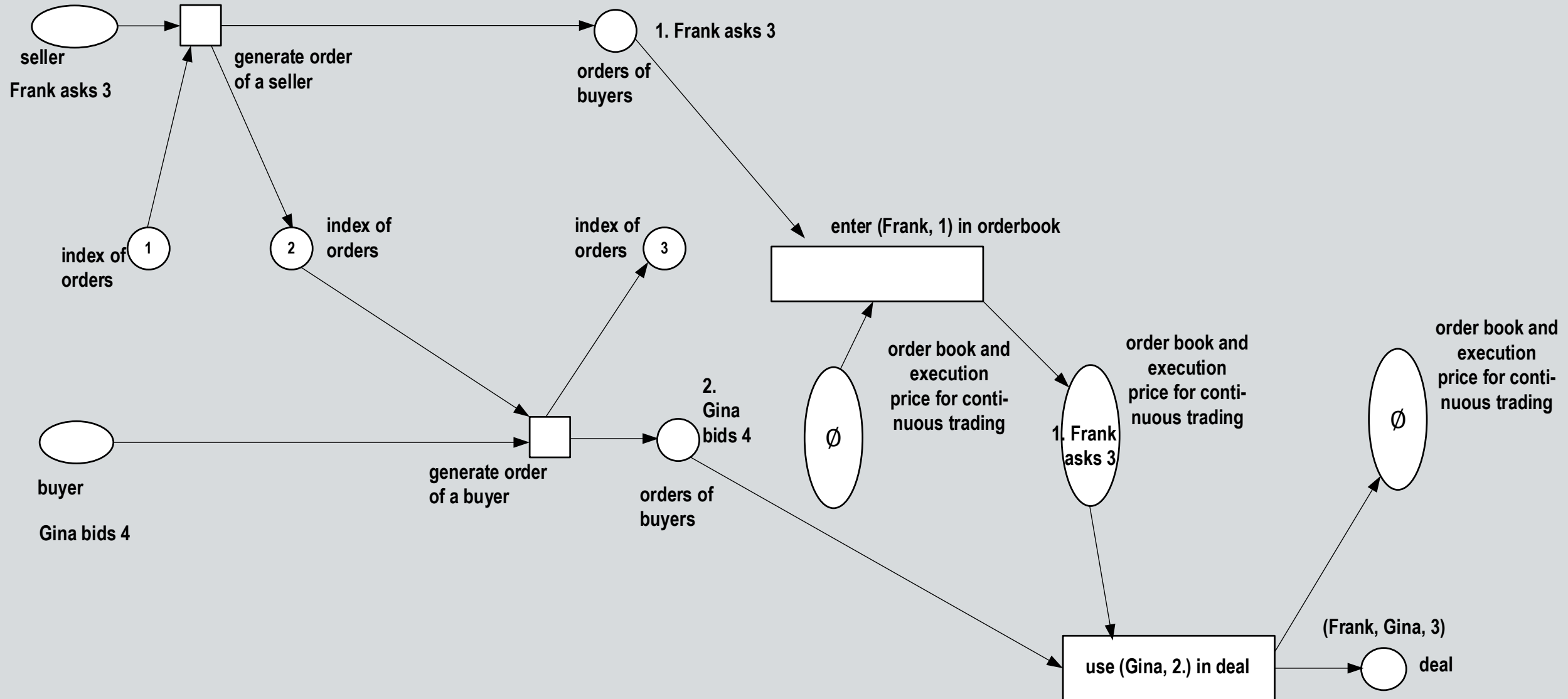




# Stock exchange: continuous trading: empty order book & direct match



# Stock exchange: continuous trading: empty order book & direct match



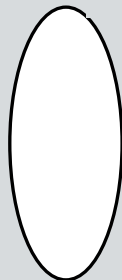
# Stock exchange: continuous trading: "full" order book & direct match of sell order

Frank asks 3



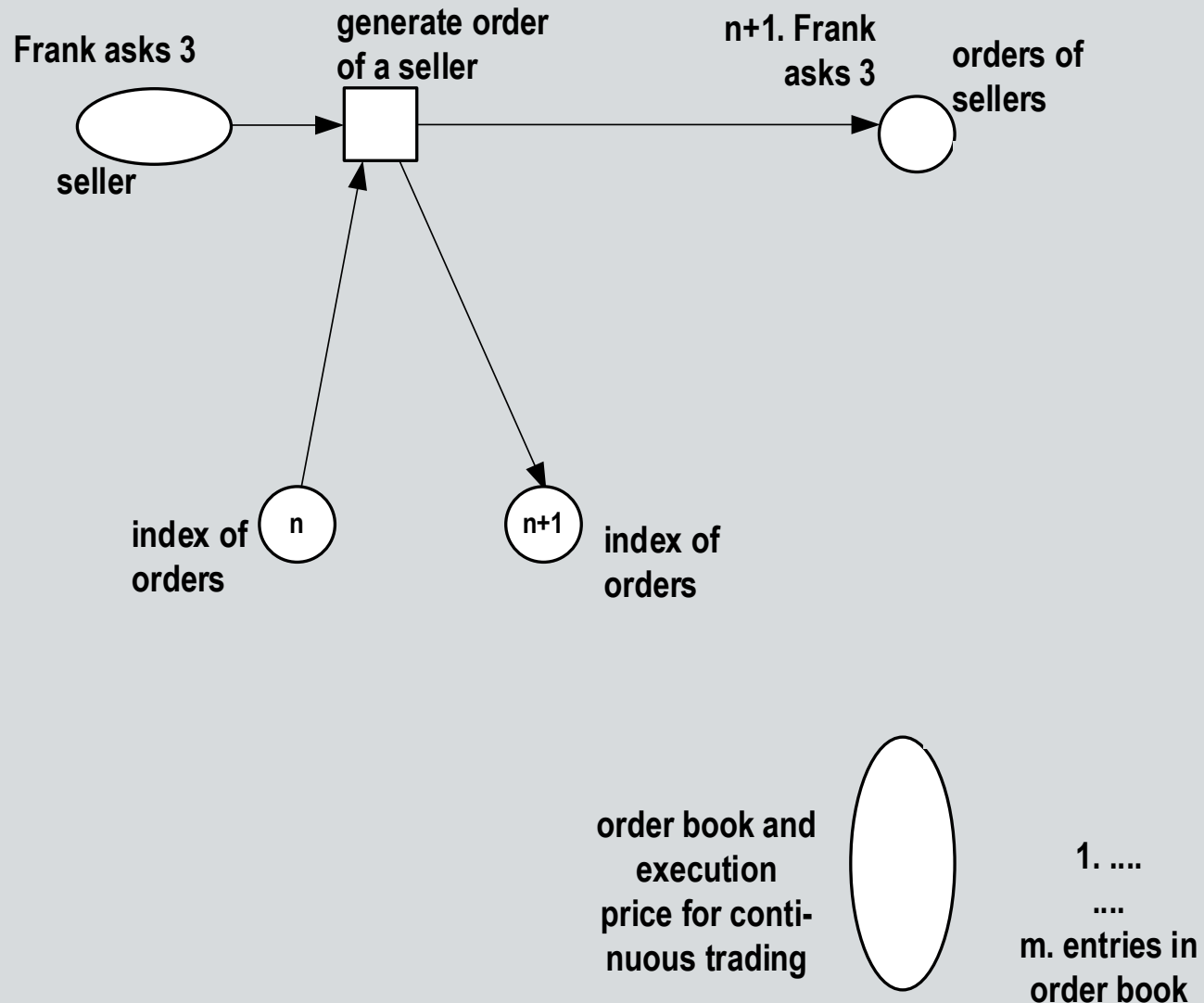
seller

order book and  
execution  
price for conti-  
nuous trading

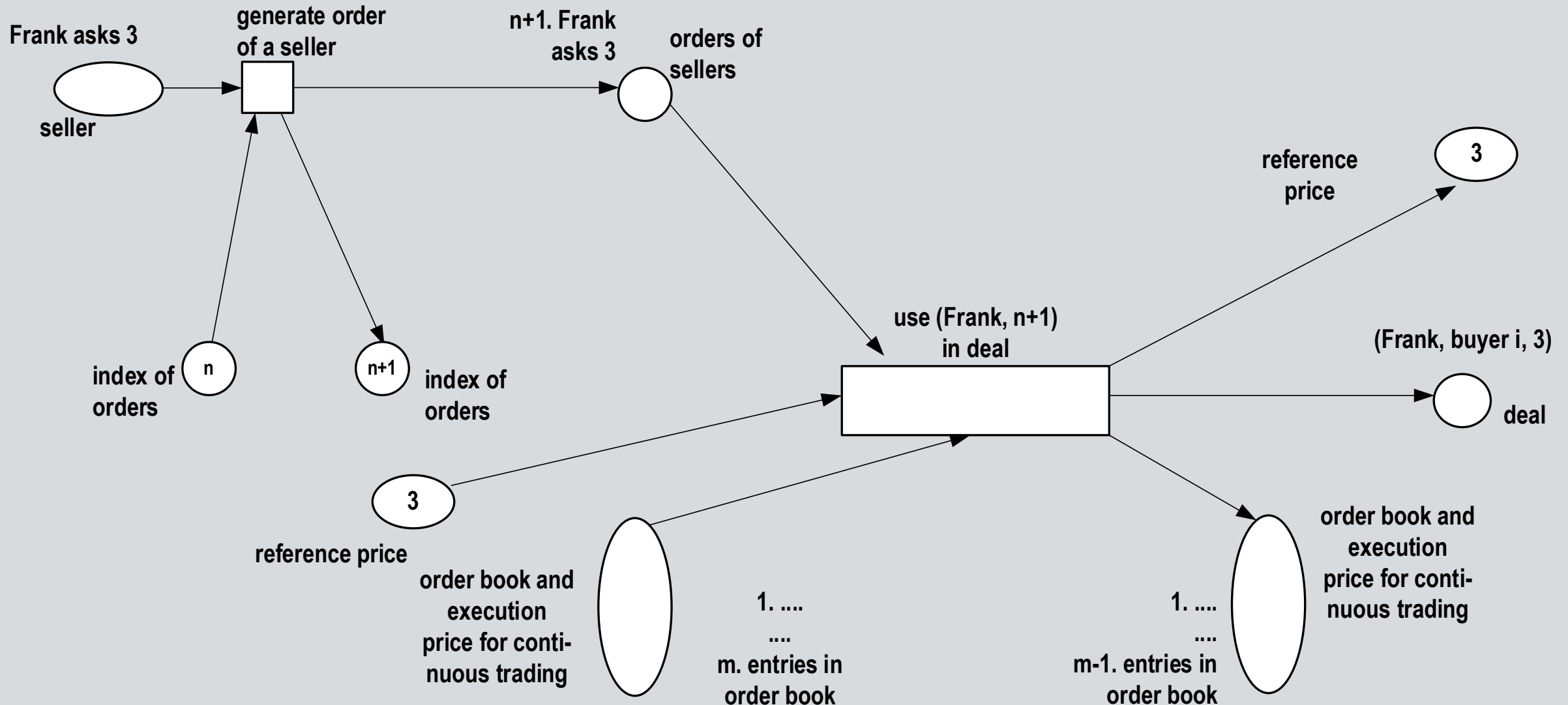


1. ....  
....  
m. entries in  
order book

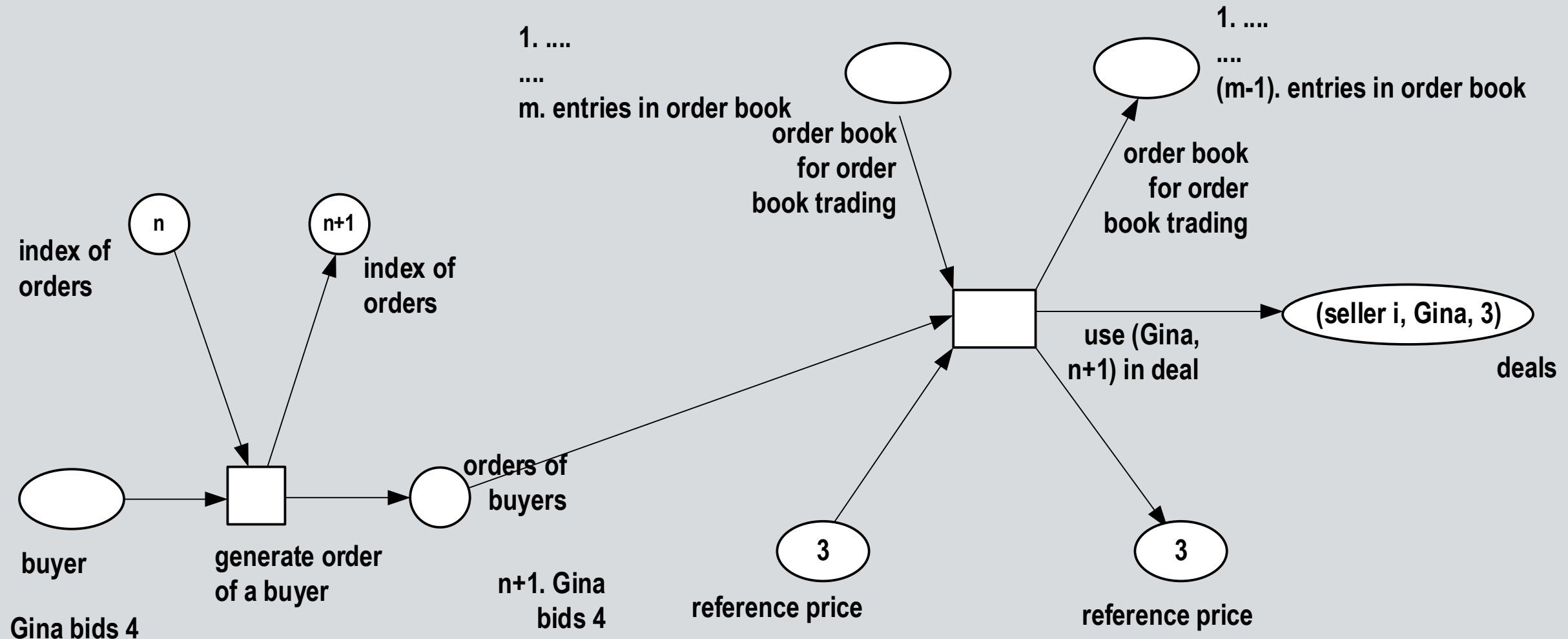
# Stock exchange: continuous trading: "full" order book & direct match of sell order



# Stock exchange: continuous trading: "full" order book & direct match of sell order



# Stock exchange: continuous trading: "full" order book & direct match of buy order





# Agenda

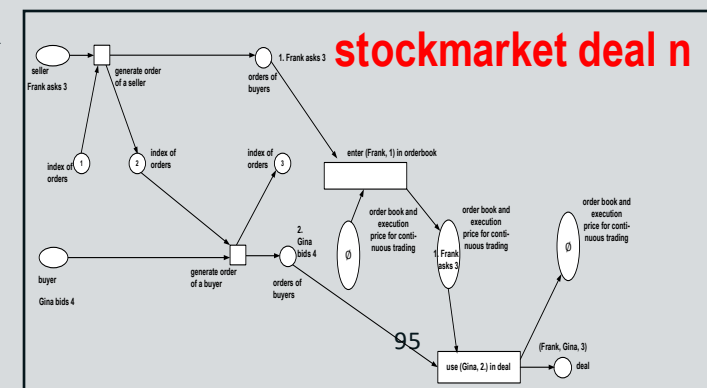
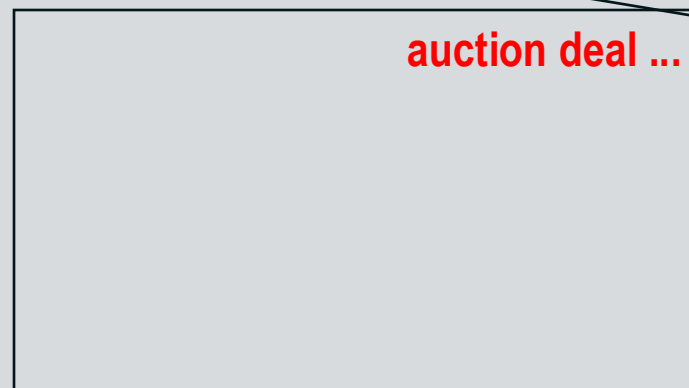
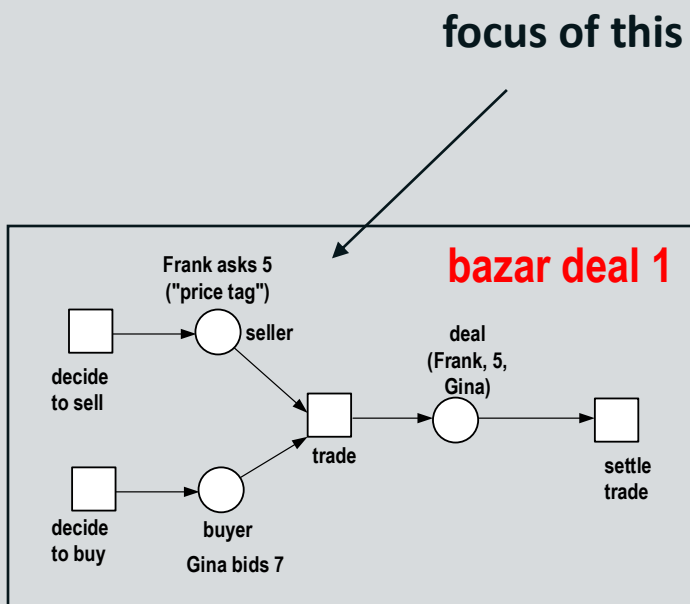
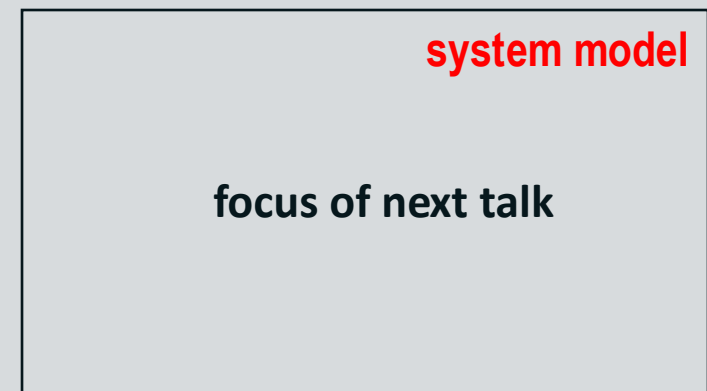
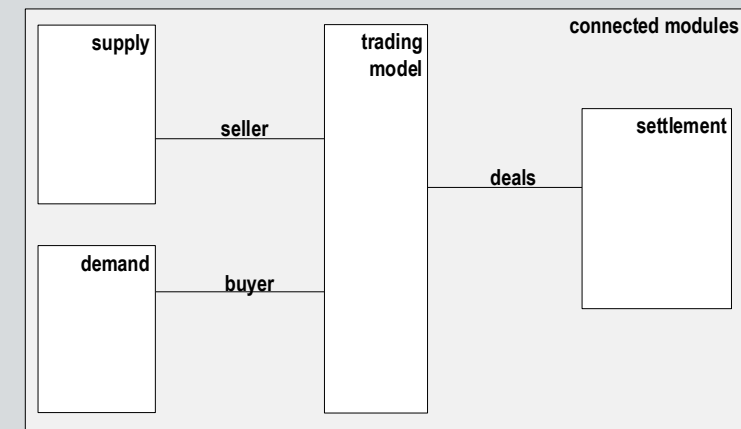
This talk in a nutshell

1. Understanding the digital world
2. Modeling markets
3. Conclusions



# A digital model of markets

discrete steps that partially order  
“the rules and arrangements for trading”,  
i.e. their cause, effect, and independence



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