TYPICAL COMBINATORIAL ENGINEERING SCHEMES (FRAMEWORKS) FOR SUPPORT OF MODULAR SYSTEMS WITH MORPHOLOGICAL MODEL (tutorial)

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TYPICAL COMBINATORIAL ENGINEERING SCHEMES (FRAMEWORKS) FOR SUPPORT OF MODULAR SYSTEMS WITH MORPHOLOGICAL MODEL

Integrated material (as tutorial, conceptual level)

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Plan

PART 1. General glance
(system analysis and composite alternatives, system engineering frameworks, four-layer architecture, hierarchical morphological model, example of building)

PART 2. Combinatorial schemes
2.1.design of hierarchical system model 2.2.system evaluation 2.2.system design/synthesis 2.4.detection of system bottlenecks 2.5.system improvement 2.6.auxiliary scheme: aggregation of modular solutions 2.7.multistage design (design of system trajectory) 2.8.combinatorial evolution and forecasting

PART 3. Illustration applied examples:
3.1.design of team 3.2. improvement of telephony network 3.3.network extension
3.4.Evolution of DSS COMBI
3.5.Evolution and forecasting of multimedia transmission standard MPEG
3.6.Evolution and forecasting of protocol ZigBee (sensor networks)
3.7.Evolution of wireless mobile communication systems (G1, G2, G3, G4, G5, G6), improvement of G5 3.8morphological approach to location

PART 4. Application in education
4.1.Student plan 4.2.evolution of modular courses, design, aggregation
4.3.Student individual trajectory <BS, MS, PhD, PostDoc> 4.4.Some published student projects

PART 5. Conclusion

Part 1. General glance

PLAN:

1.0.Basic author's references
1.1.System analysis and support framework for modular systems
1.2.Composition of combinatorial system schemes (conceptual level)
1.3.Life cycle
1.4.Combinatorial system engineering schemes/frameworks
1.5.General (architectural) glance to combinatorial engineering frameworks
1.6.Composite alternatives-modular systems
1.7.Four-layer architecture: (i)combinatorial problems, (ii)composite problems, (iii)typical system problems/frameworks, (iv)application domains
1.8.Resource management scheme
1.9.Hierarchical morphological system model
1.9.1.Illustration and example
1.9.2.Example for two-floor building

1.0.Basic author's references

I.Books:

1.1.Levin M.Sh. Modular System Design and Evaluation, Springer, 2015.

1.2.Levin M.Sh. Composite Systems Decisions. Springer, 2006.

1.3.Levin M.Sh. Combinatorial Engineering of Decomposable Systems, Springer, 1998.

II.Papers:

2.1.Levin M.Sh. Towards decision support technology platform for modular systems. Elect. Prepr., 10 p., Aug. 23, 2014, http://arxiv.org/abs/1408.5494[cs.SY]

2.2.Levin M.Sh. Note on combinatorial engineering frameworks for hierarchical modular Systems. Elect. Prepr., 11 p., Mar. 29, 2013, http://arxiv.org/abs/1304.4965[cs.AI]

2.3.Levin M.Sh. Towards design of system hierarchy (research survey). Elect. Prerp. 36 p., Dec. 7, 2012, http://arxiv.org/abs/1212.1735[math.OC]

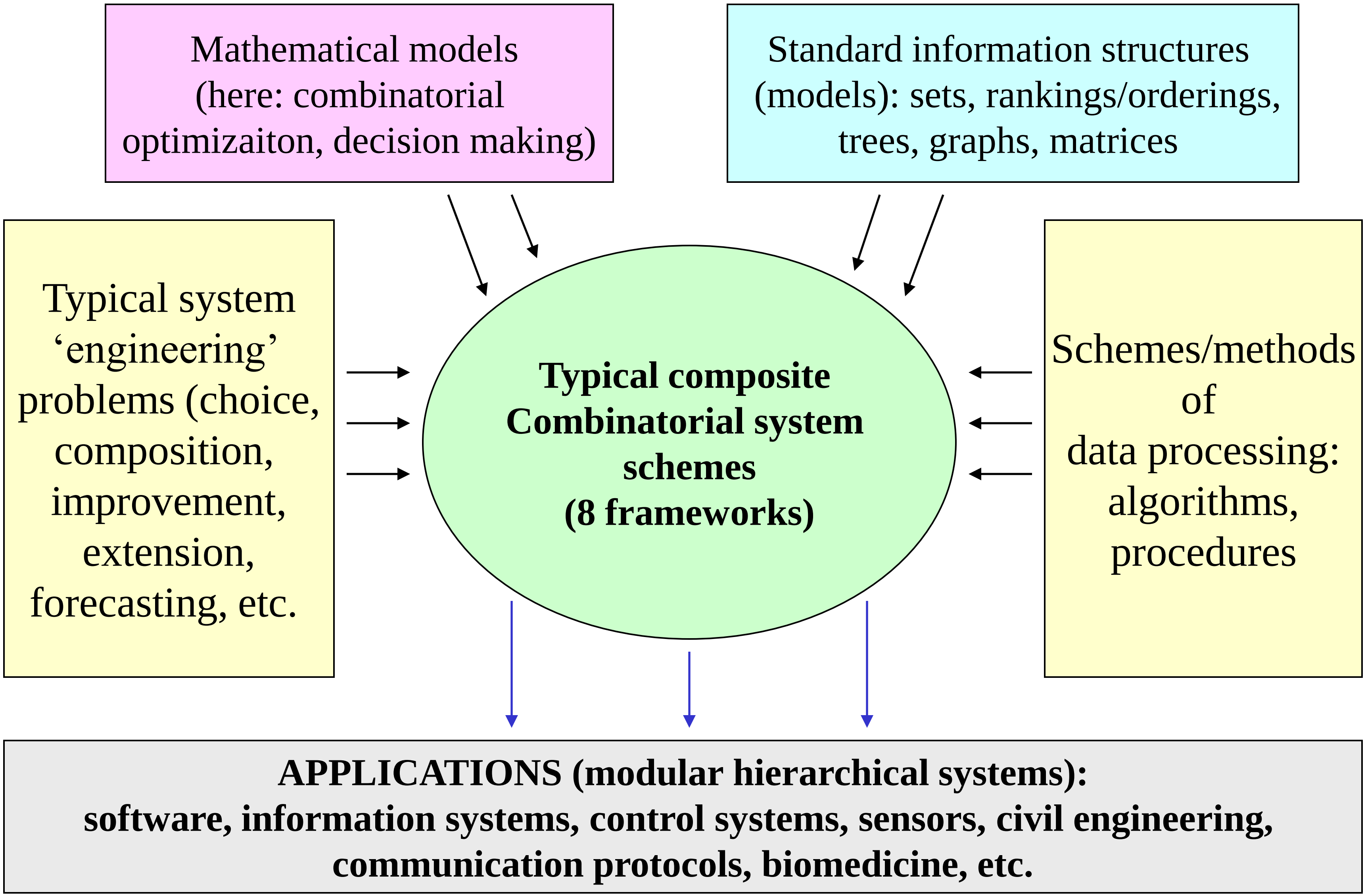
2.4.Levin M.Sh. Four-layer framework for combinatorial optimization problem domain. Advanced in Engineering Software, 42(12), 1089-1098, 2011.

1.1.System analysis and this work

SYSTEM ANALYSIS:
A.Generalized approaches and methods for systems:
modeling, analysis, evaluation, synthesis, etc.
B.Applications in various fields:
computer systems, information systems, control systems,
mechanical systems, electronic systems, etc.

THIS WORK:
A.Generalized approaches and methods (for modular systems):
modeling, evaluation, synthesis, , analysis of evolution;
Basic support level: combinatorial optimization models and multicriteria decision making
B.Applications in various fields:
computer systems, communication systems, control systems, management,
organization-technical systems, biomedicine, civil engineering, education

1.2.Composition of combinatorial system schemes (conceptual level)



1.3.Life cycle –system problems /schemes (‘technological/engineering’)

Life cycle
(12 years-> 2 years):
1.Design
2.Manufacturing
3.Testing
4.Warehousing
5.Marketing
6.Utilization
7.Maintenance
8.Re-cycling

COMBINATORIAL SYSTEM SCHEMES
(system problems) (7+1)

1.System modeling (structural model as AND-OR graph)
2.System Evaluation
3.Combinatorial synthesis (design, design of system configuration)
4.Detection of system bottlenecks
5.Improvement, extension, adaptation, reconfiguration
6.Multi-stage design (design of system trajectory)
7.Combinatorial evolution, forecast (trajectory of system generation, forecast)
8.PLUS: aggregation of modular solutions

Hierarchical system model:
software, plan, apparatus, standard, protocol, etc.

Models of combinatorial optimization and decision making:
knapsack, multiple choice problem, ranking/sorting, morphological clique, assignment/location, clustering, spanning trees, consensus/median design, etc.

COMBINATORIAL SYSTEM SCHEMES (problems) (7+1)

1.System modeling: systematization, application

2.Evaluation (system and its parts): сиsystematization, scales (new), problems/models of integration

3.Combinatorial synthesis: systematization, morphological clique model, models with multiset-like estimates

4.Detection of bottlenecks: systematization, new schemes, detection of element groups, dynamical problems (clique-based fusion)

5.Improvement, extension, adaptation, reconfiguration: systematization, new schemes/models

6.Design of trajectory for modular system solution: new schemes/models

7.Modeling of system combinatorial evolution, forecasting (i.e., trajectory of system generation, system forecast): new schemes/models

8.Aggregation of modular system solutions: systematization, new schemes/models

PLUS: Real world applied examples in various fields (30..50)

1.5.General ‘glance’ to combinatorial engineering frameworks

1. Design of hierarch. system model:	2. Evaluation of hierar. system:	3. Combinatorial synthesis:	4. Detection of bottlenecks:	5. Improvement:	6. System trajectory:	7. System evolution, forecast:
expert schemes, hierar. clustering, ontology, systematization	new scales (lattices, multisets), evaluation methods, integration of estimates, рации оценок, systematization	hierar. morphol. method,- model of morphol. clique, multiset based models (+ knapsack-like models)	new schemes, dynamical problems (clique, etc.), systematization	new schemes/ models (morphol. clique, multiple choice problem, spanning problems), systematization	new schemes (hierar. morphol. method, knapsack-like models), systematization	new schemes (morphol. method, knapsack-like models), др.) systematization

1.6.MODULAR SYSTEM – OBJECTS UNDER EXAMINATION AND PROBLEMS

Decision making
(since 1957, H. Simon)

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Alternative → **Composite alternative**

Problems: Generation, analysis, evaluation, comparison, choice/selection

Problems (levels: element, composite alternative): analysis/evaluation, comparison, choice/ selection, synthesis, aggregation, modification, modeling of evolution, forecasting

COMPOSITE ALTERNATIVE (MODULAR SYSTEM):
1.Elements: set 2.Element relationship (e.g., compatibility) 3.System structure

OBJECTS UNDER EXAMINATION:
1.Element/alternative 2.Set of alternatives
3.Element estimate 4.Element compatibility 5.Compatibility estimates
6.System structure (e.g., tree, digraph) 7.Estimates of structures (proximity, etc.близости)

EXAMPLES OF STRUCTURAL MODELS:
1.Element of set 2.Set 3.Chain 4.Tree 5.Graph (digraph)
6.Composition of objects (e.g., tree and several sets)

1.7.Four-layer structure: problem/models-methods/procedures-applications

Layer 4: Applications (for modular systems)

- Soft-ware
- Rertrie-val
- Marke-ting-
- Mana-gement
- Com-muni-cation
- Stan-dards
- Biome-dicine
- Requi-rements Eng.
- Educa-tion
- Etc.

Layer 3: Typical system problems–schemes (frameworks)

- Design of hierar. system model
- System evalua-tion
- System syn-thesis
- System bottle-necks
- System impro-vement, extension
- System Trajec-tory-
- System evolution, forecast
- System aggre-gation

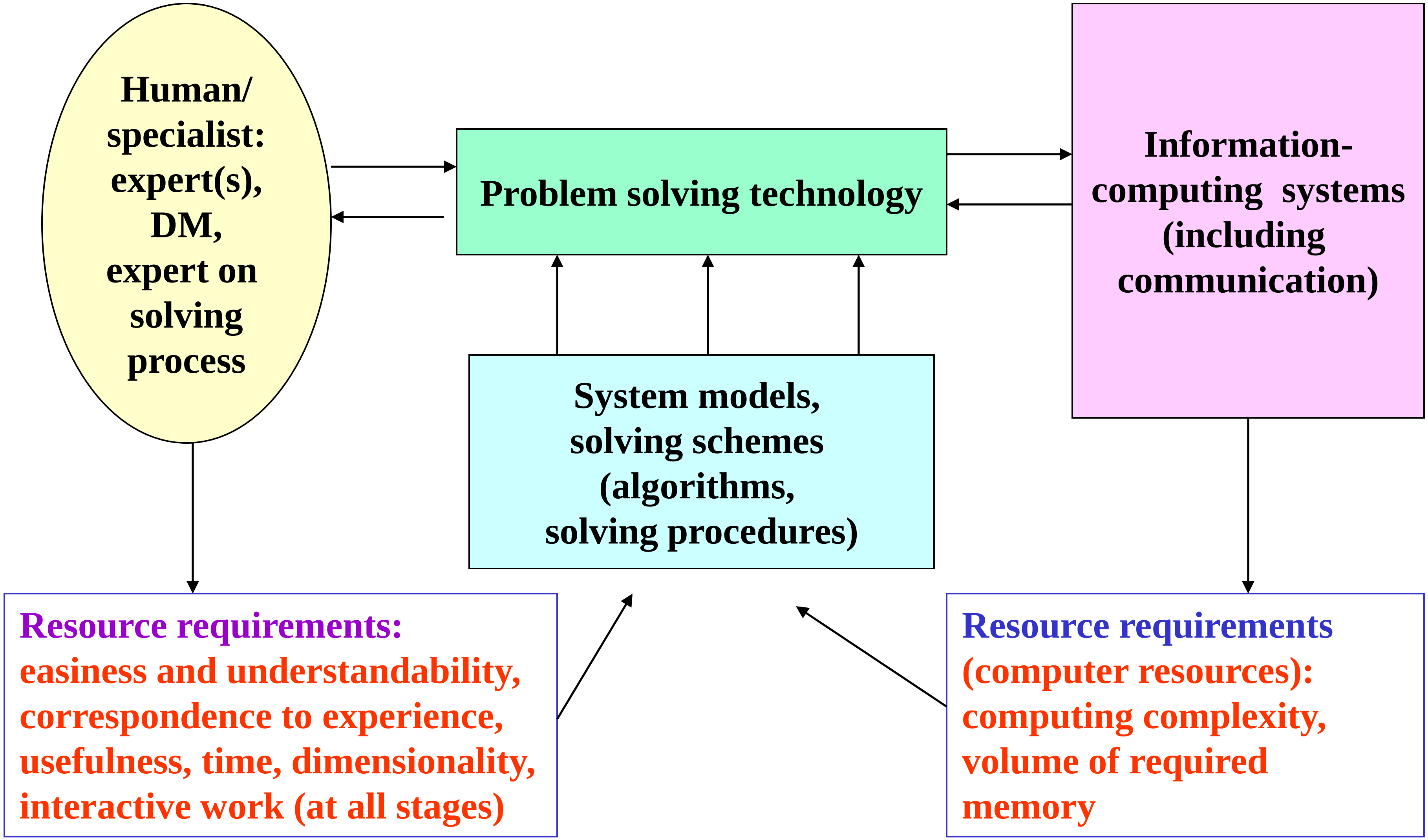
Layer 2: Composite problems/models/procedures

- Multicriteria combinatorial optimization problems (knapsack, multiple choice problem, assignment/location, spanning problems, etc.)
- Methods for design of hierarchies
- Methods for design of consensus/ median
- . . .

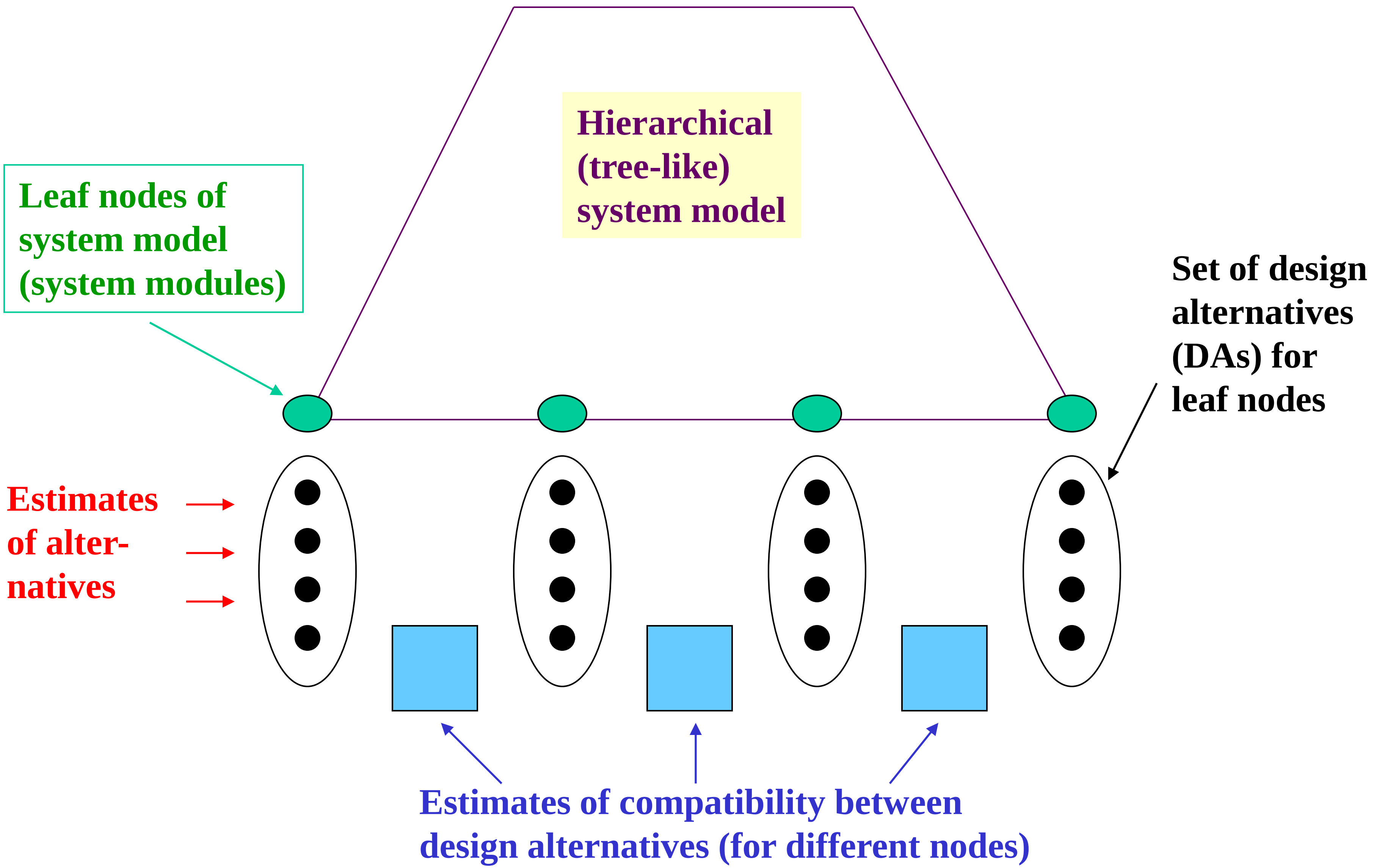
Layer 1: Basic problems of combinatorial optimization and decision making

- Ranking/ sorting
- Knap-sack
- Multiple choice problem
- Cluste-ring
- Assign-ment
- Spanning problems
- Clique
- Etc.

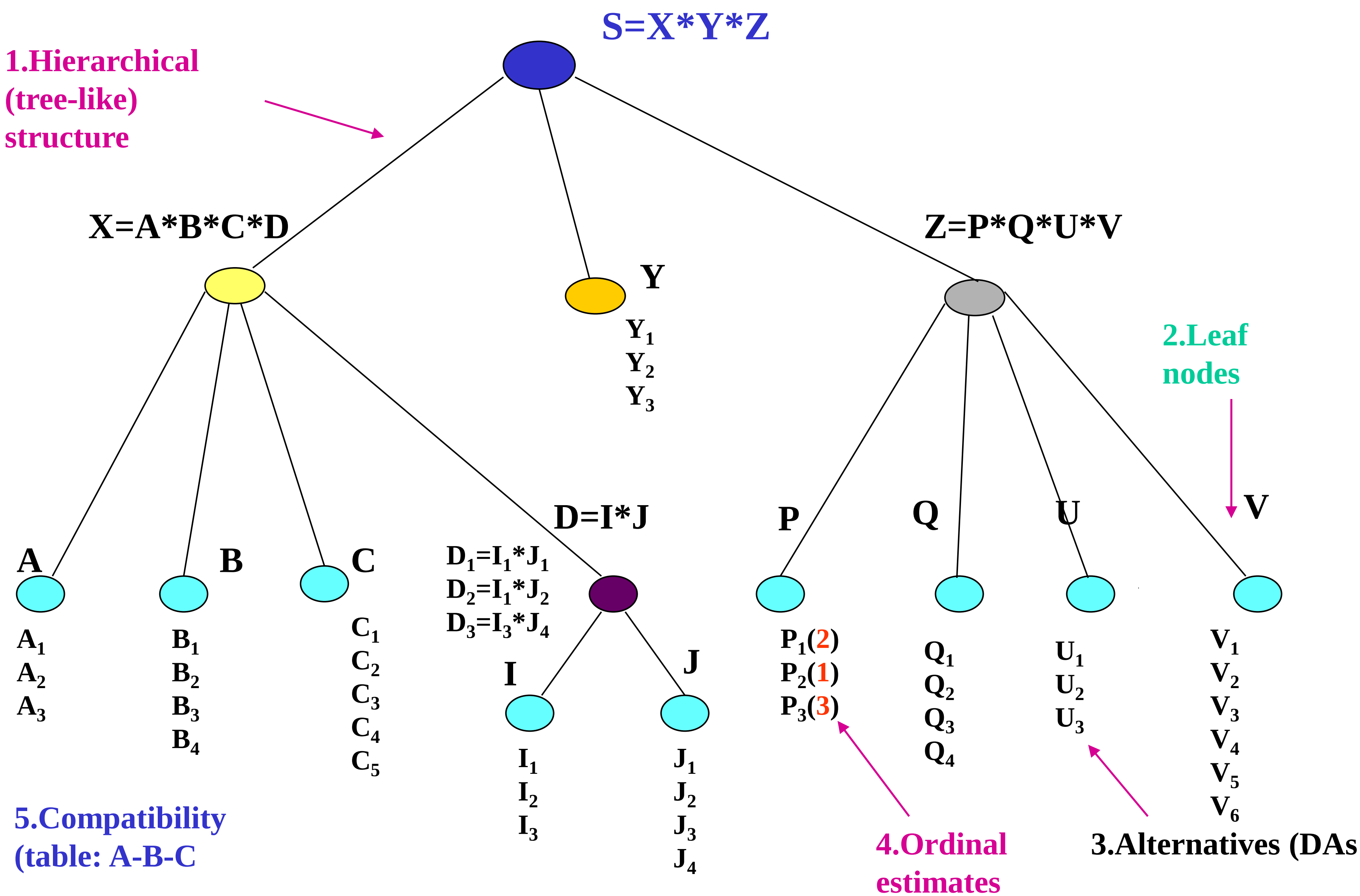
1.8.Towards resource requirements



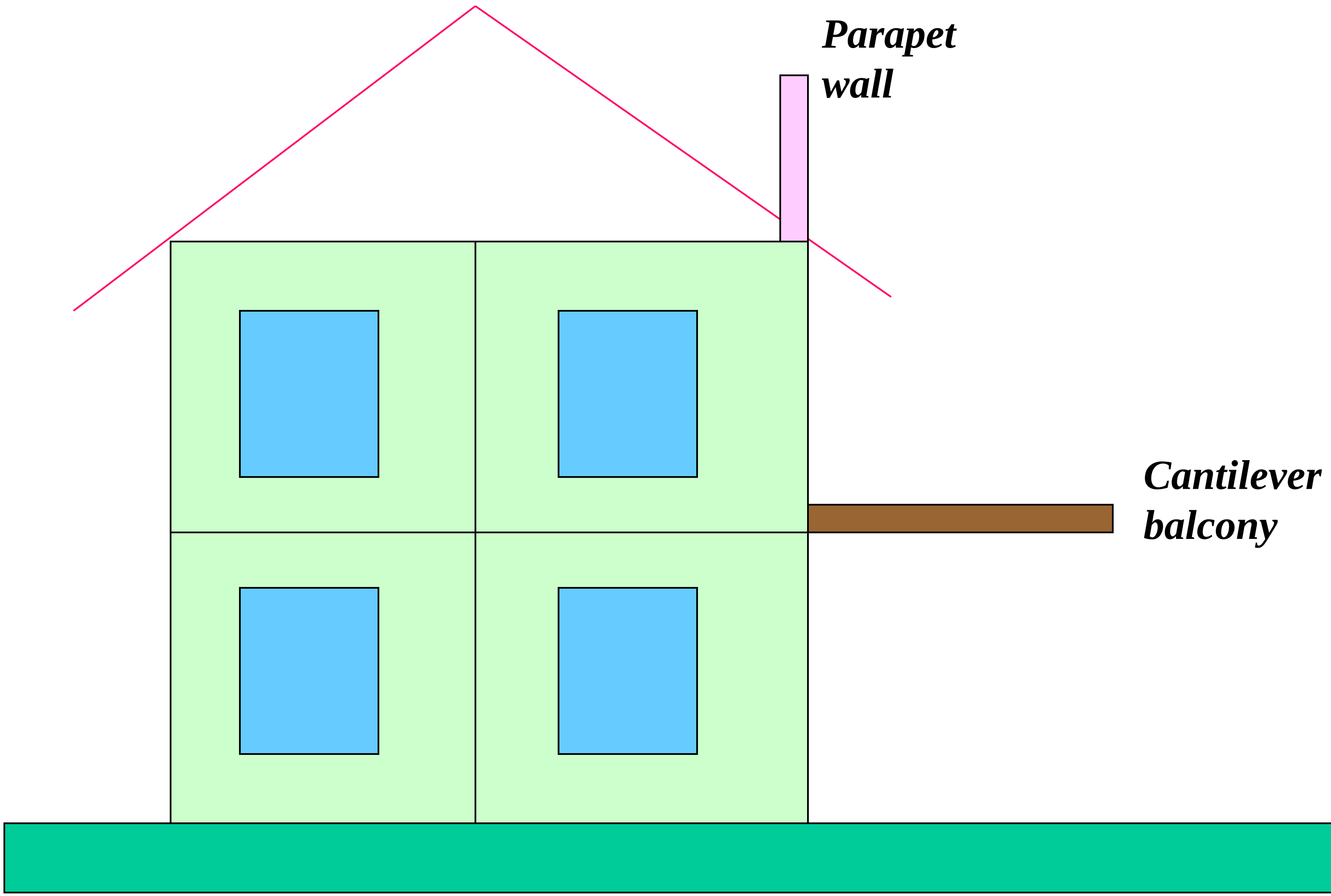
1.9.Hierarchical system model (and morphological system model)



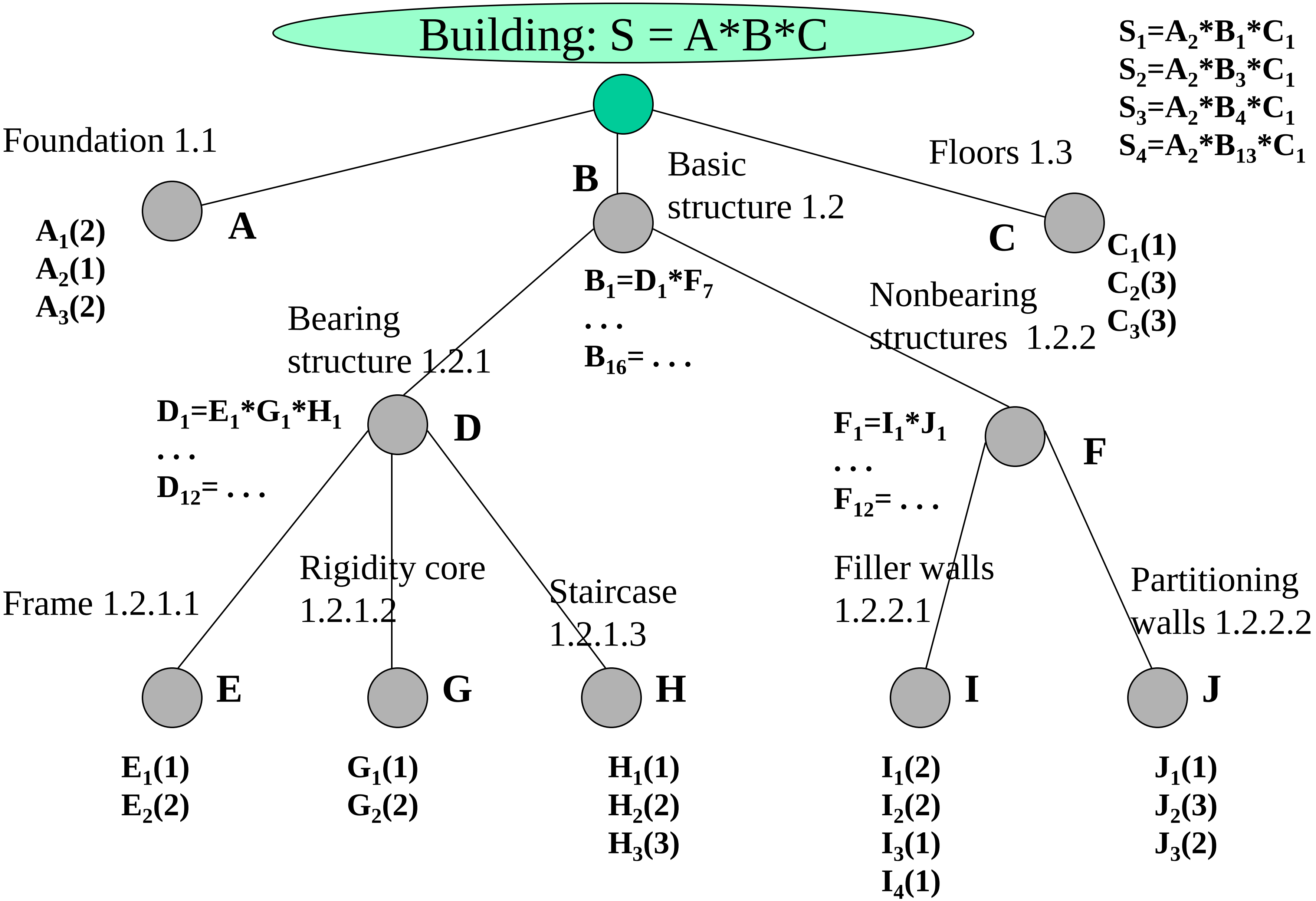
1.9.1.Morphological model: example



1.9.2.Example of two-floor building



1.9.2.Hierarchical morphological model of building



Alternatives

Foundation A : A_1 (strip foundation), A_2 (bedplate foundation), A_3 (isolated parts)

Frame E : E_1 (monolith frame), E_2 (precast frame)

Rigidity core G : G_1 (monolith rigid core), G_2 (precast rigid core)

Staircase H : H_1 (monolith staircase), H_2 (precast staircase), H_3 (composite staircase)

Filler walls I : I_1 (small elements), I_2 (curtain panel walls),
I_3 (precast enclose panel walls), I_4 (frame walls)

Partitioning walls J : J_1(precast panel walls), J_2 (small elements), J_3 (frame walls)

Floors C : C_1 (monolith slabs), C_2 (composite slabs), C_3 (precast slabs)

Part 2. Combinatorial schemes (frameworks)

PLAN:

2.0.Basic author's references
2.1.Scheme 1: Design of hierarchical system model
2.2.Scheme 2: System evaluation
2.3.Scheme 3: System design/synthesis
2.4.Scheme 4: Detection of system bottlenecks
2.5.Scheme 5: System improvement
2.6.Auxiliary scheme: Aggregation of modular solutions
2.7.Scheme 6: Multistage design (design of system trajectory)
2.8.Scheme 7:Combinatorial evolution and forecasting

2.0.Basic author's references - A

I.Books:

1.1.Levin M.Sh. Modular System Design and Evaluation, Springer, 2015.
1.2.Levin M.Sh. Composite Systems Decisions. Springer, 2006.
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2.2.Levin M.Sh. Improvement/extension of modular systems as combinatorial reengineering (survey). Elect. Prepr., 24 p., Apr. 17, 2013, http:arxiv.org/abs/1304.4965[cs.AI]
2.3.Levin M.Sh. Towards combinatorial evolution of composite systems. Exp. Syst. with Appl., 40(4), 1342-1351, 2013.
2.4.Levin M.Sh., Towards multistage design of modular systems. Elect. Prepr. 13 p., Jun 19, 2013 http://arxiv.org/abs/1306.4635[cs.AI]
2.5.Levin M.Sh. Towards detection of bottlenecks in modular systems.Elect. Prepr., 12 p., Jun 1, 2013, http://arxiv.org/abs/1306.0128 [cs.AI]
2.6.Levin M.Sh. Note on evaluation of hierarchical modular systems. Elect. Prepr. 15 p., May 21, 2013, http://arxiv.org/abs/1305.4917[cs.AI]
2.7.Levin M.Sh. Multiset estimates and combinatorial synthesis. Elect. Prepr., 30 p., May 9, 2012, http://arxiv.org/abs/1205.2046[cs.SY]
2.8.Levin M.Sh. Combinatorial optimization in system configuration design. Aut. Rem. & Control, 70(3), 519-561, 2009.

II.Papers:

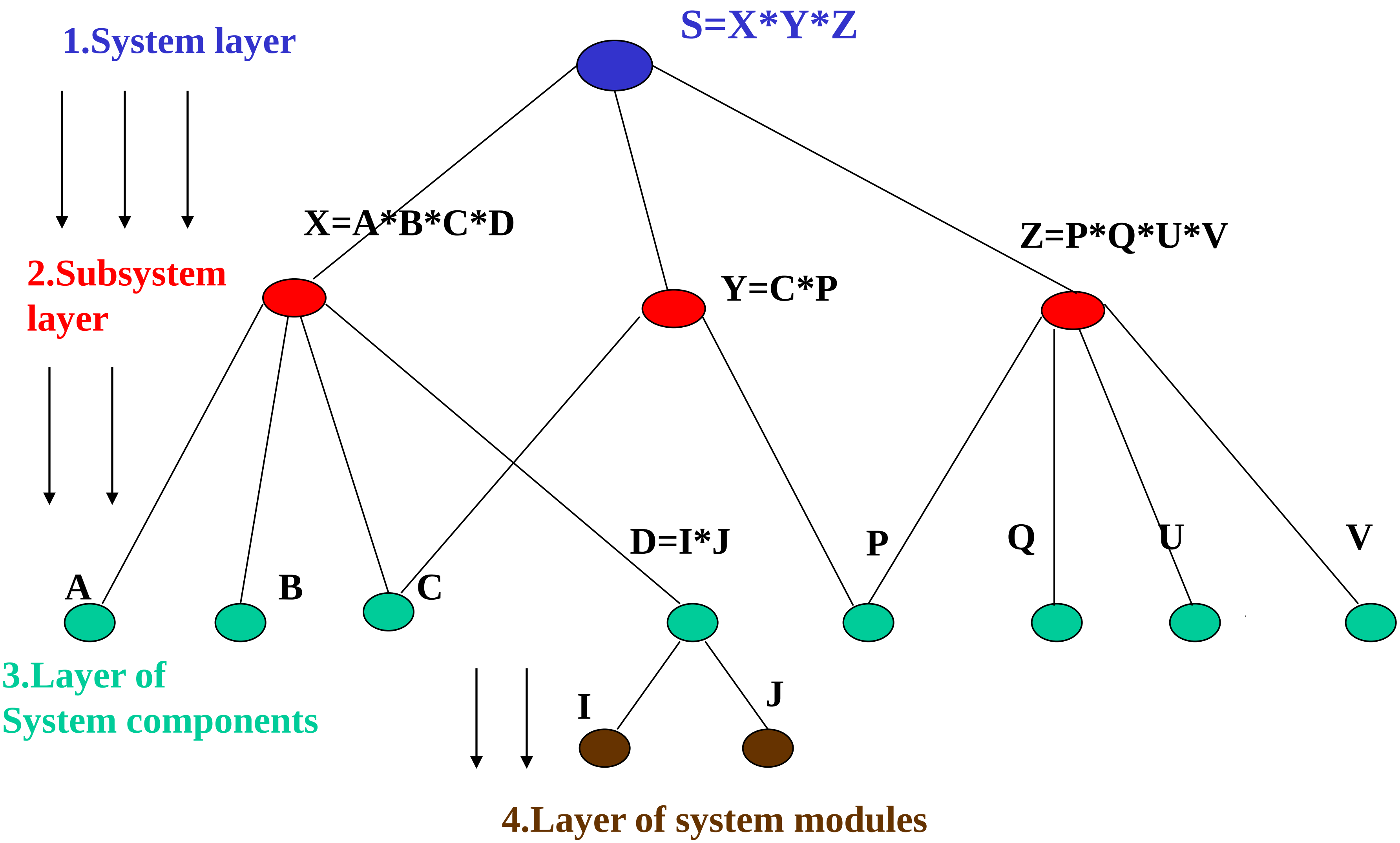
2.9.Levin M.Sh. Aggregation of composite solutions: strategies, models, examples. Electr. prepr., Nov. 29, 2011. http://arxiv.org/abs/1111.6983[cs.SE]
2.10.Levin M.Sh. Towards integrated glance to restructuring in combinatorial optimization. Elect. Ptepr., 31 p., Dec. 20, 2015, http://arxiv.org/abs/1512.06427[cs.AI]
2.11.Levin M.Sh. Towards clique-based fusion of graph streams in multi-function system testing. Informatica (Lith), 23(3), 391-404, 2012.
2.12.Levin M.Sh. Combinatorial technological system problems (examples for communication systems. Proc. of Int. Conf. on Systems Engineering and Modeling ICSEM 2007, 24-32, 2007.
2.13.Levin M.Sh. Modular system synthesis: example for composite packaged software. IEEE Trans. on SMC, Part C, 35(4), 544-553, 2005.
2.14.Levin M.Sh. Combinatorial evolution of composite systems. Proc. of the 16th Eur. Meeting on Cybernetics & Syst. Research, EMCSR'2002, vol. 1, 275-280, 2002.
2.15.Levin M.Sh. Towards combinatorial analysis, adaptation, and planning of human-computer systems. Applied Intelligence, 16(3), 235-247, 2002.
2.16.Levin M.Sh. System synthesis with morphological clique problem: fusion of subsystem evaluation decisions. Information Fusion, 2(3), 225-237, 2001.
2.17.Levin M.Sh. Hierarchical morphological multicriteria design of decomposable systems. Concurrent Engineering: Res. & Appl., 4(2), 111-118, 1996.

2.1.Scheme 1: Design of hierarchical system model

Methods:

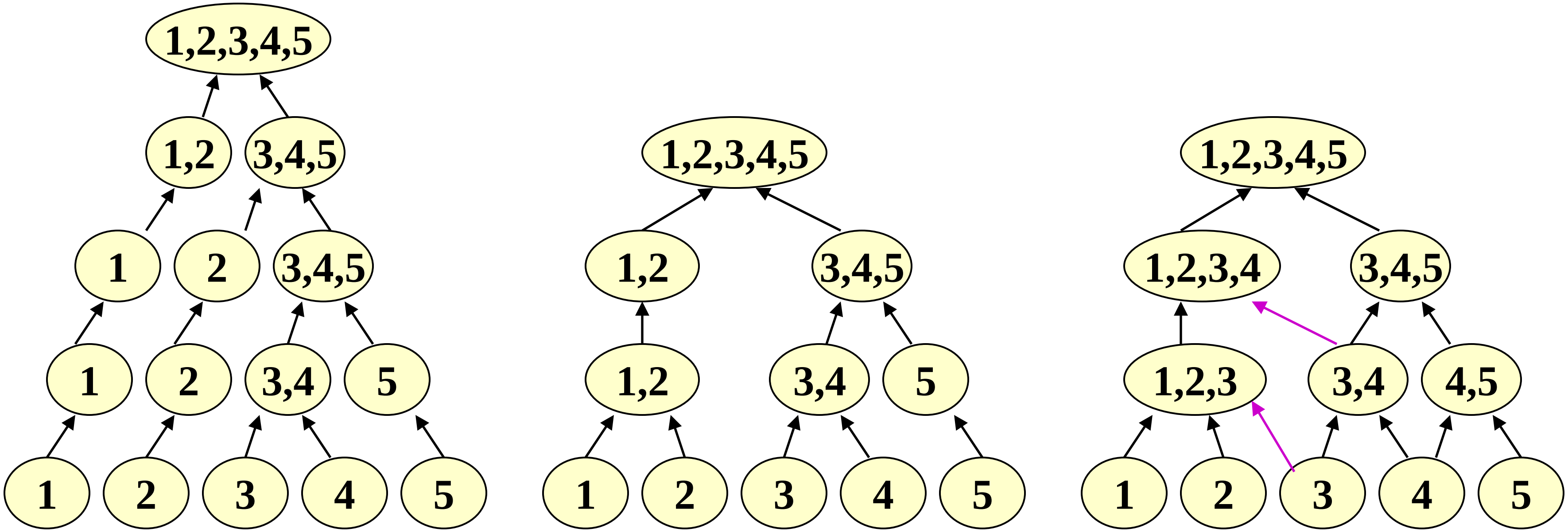
1.Procedure 'Top-Down' (partitioning, decomposition)
2.Hierarchical clustering ('Bottom-Up')
3.Design of ontology
4.Design of spanning tree (e.g., minimum spanning tree,
minimum Steiner tree,
Spanning tree with maximal terminal vertices)
5.Design of multi-layer (multi-tier) structures
(layers, topology at each layer, relationship between layers)
6.Design of morphological system model

Example: design of hierarchical system model 'Top-Down'



Examples: Design of hierarchical system model 'bottom-up'

Initial data: set of elements and matrix of element proximity (pair-proximity)

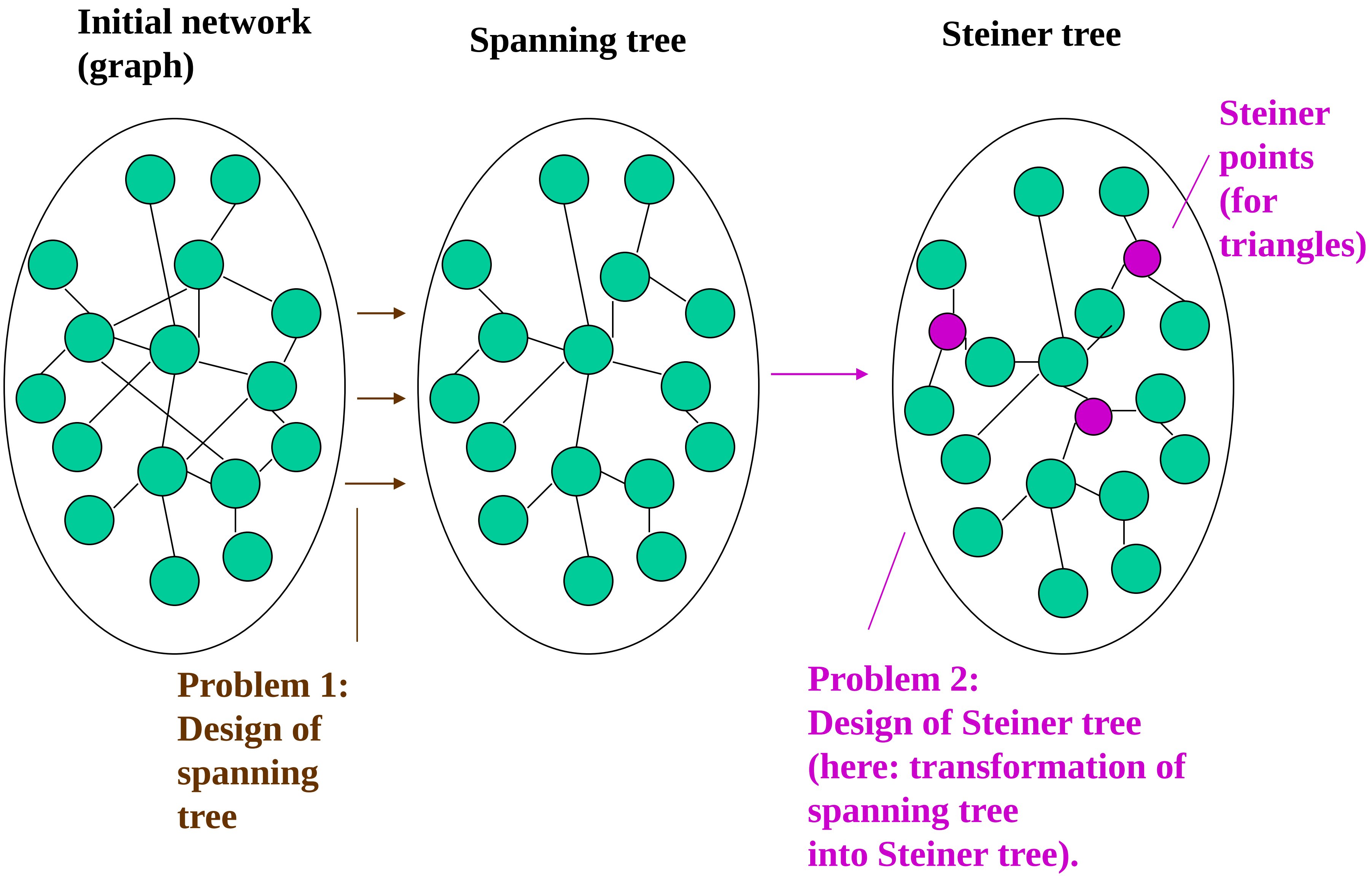


Basic agglomerative algorithm (1 step-one merging operation) Result: tree

Agglomerative algorithm (1 step – several merging operations) Result: tree

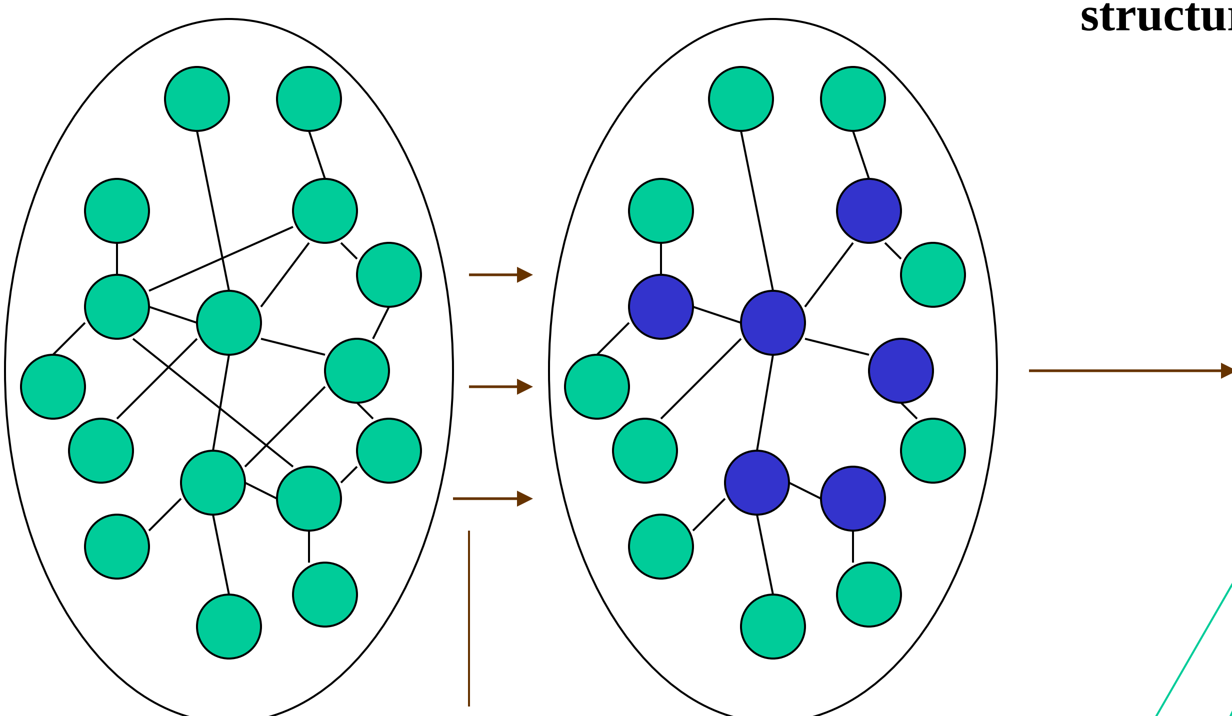
Agglomerative algorithm (1 step – several merging Operations, one element can be participated in several merging operations) Result: hierarchy

Example: Design of spanning tree and Steiner tree

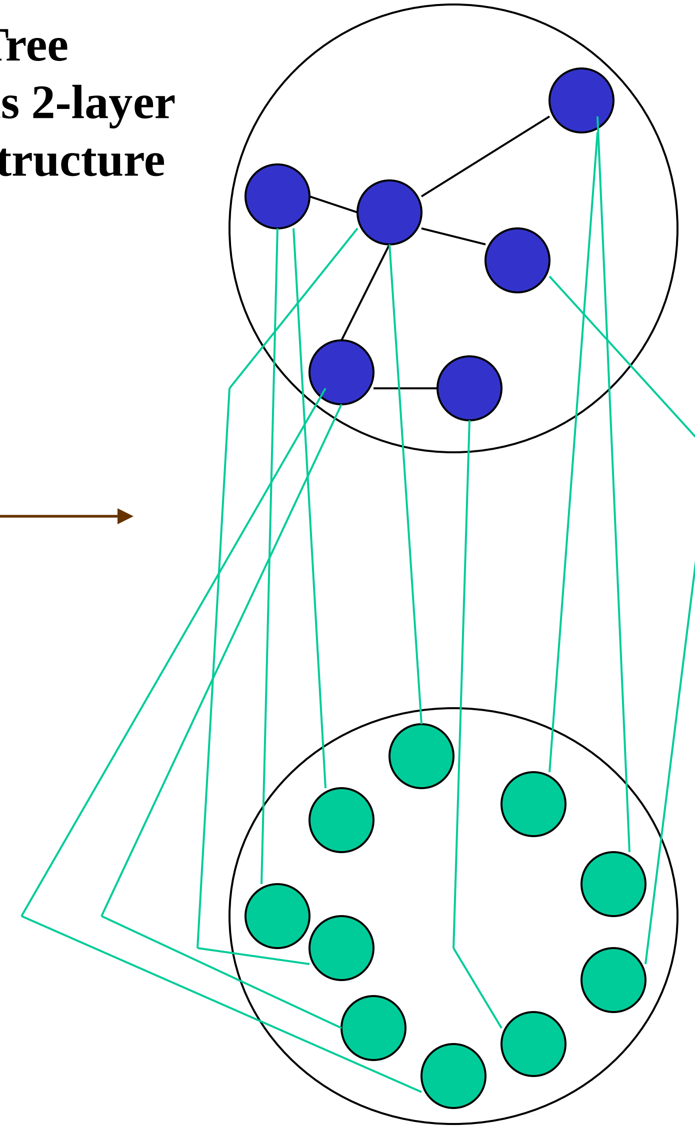


Example: design of 2-layer model – tree with maximal number of terminals (leafs)

Initial graph **Spanning tree**

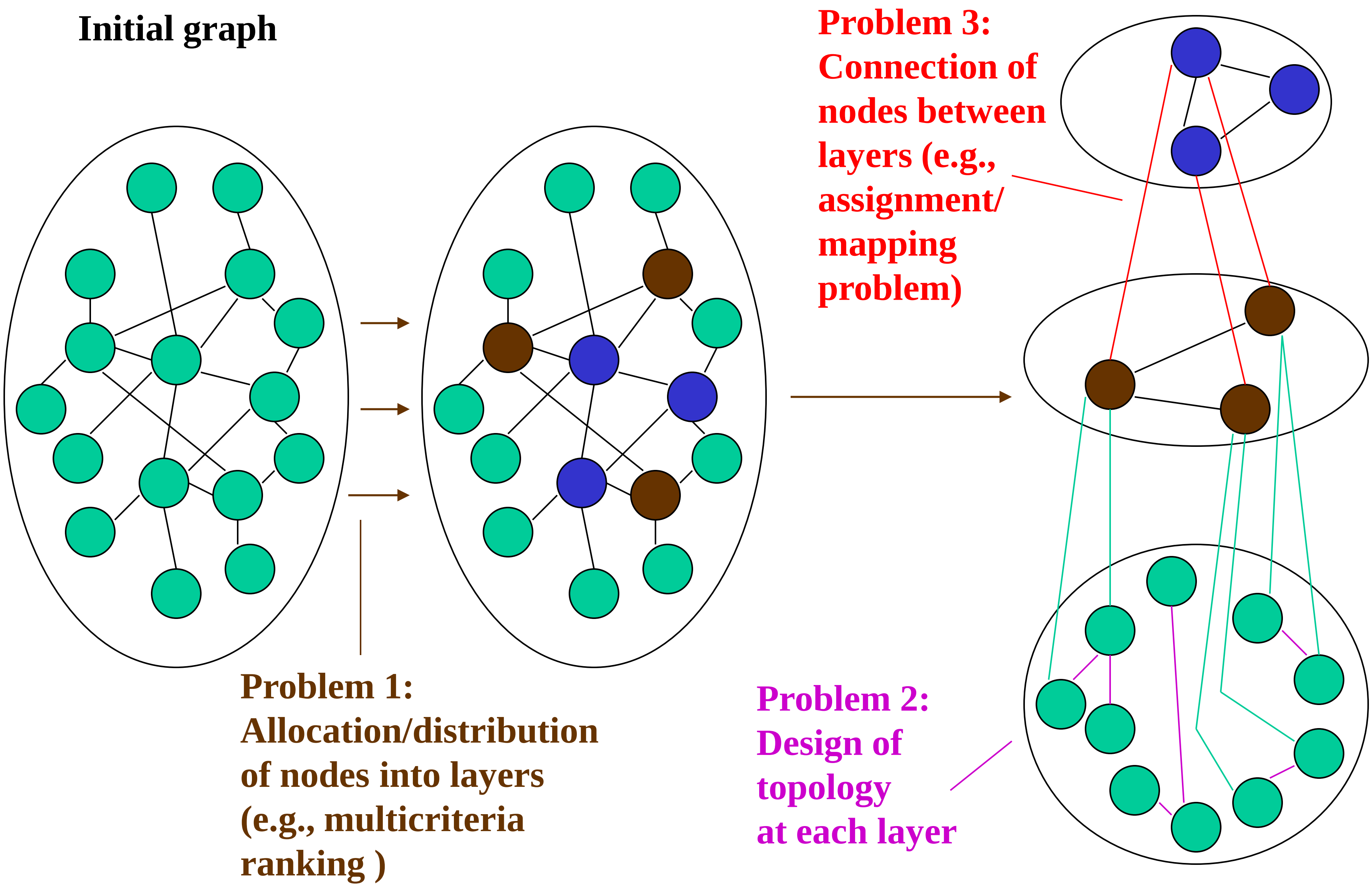


Tree
as 2-layer
structure

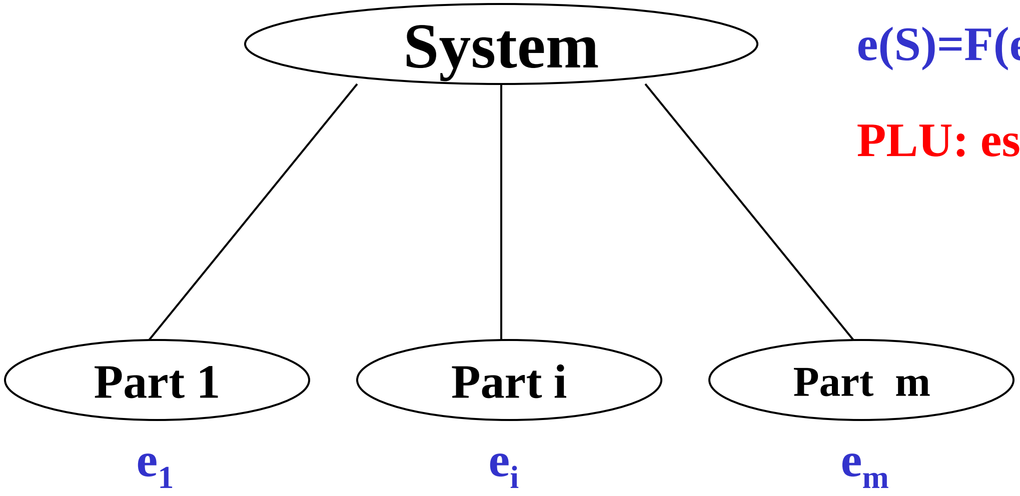


Problem 1:
Design of spanning tree with
maximal number of terminals (leafs)

Example: design of multi-layer model



2.2.Scheme 2 (Evaluation): (1) system, (2)system part/component



$e(S)=F(e_1,\ldots,e_i,\ldots,e_m)$

PLU: estimates of part compatibility

Scales/Estimate of quality:

1. Quantitative
2. Ordinal
3. Vector-like
4. Partial order (poset)

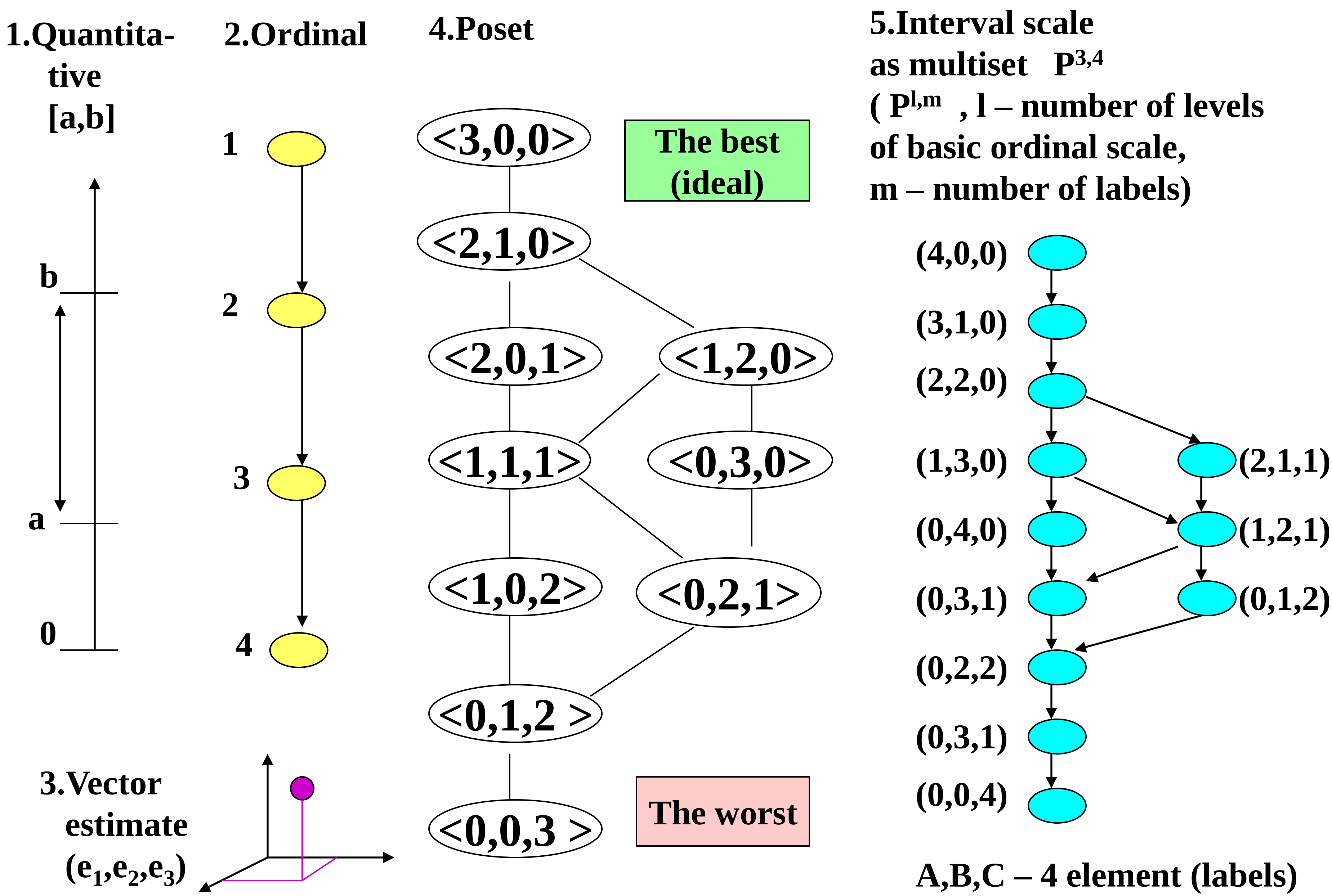
Problems:

1. Assessment (for object): measurement, calculation, probation, expert judgment, etc.
2. Transformation of scale: (e.g., quantitative scale into ordinal scale)
3. Integration os scales (i.e., several estimates into a resultant estimate)

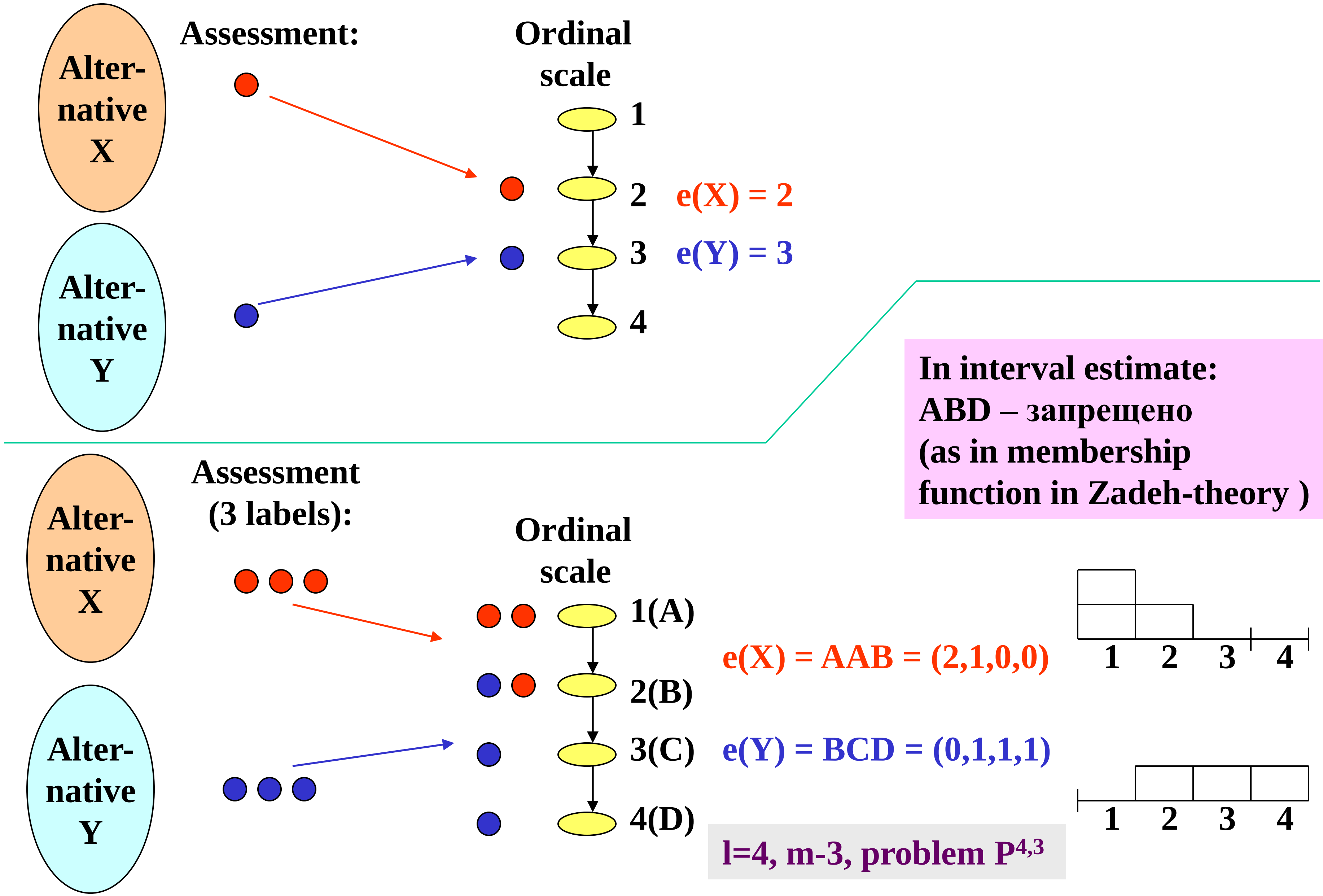
Additional problems:

(a)analysis of proximity (b)alignment (c)averaging

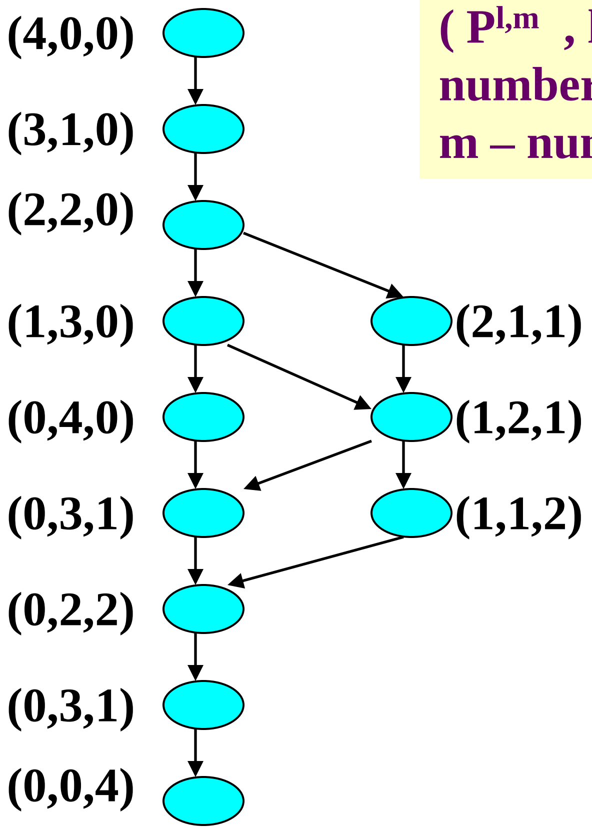
Scales


1.Quantitative [a,b]
b
a
0
2.Ordinal
1
2
3
4
3.Vector estimate (e_1,e_2,e_3)
4.Poset
<3,0,0>
The best (ideal)
<2,1,0>
<2,0,1>
<1,2,0>
<1,1,1>
<0,3,0>
<1,0,2>
<0,2,1>
<0,1,2 >
<0,0,3 >
The worst
5.Interval scale as multiset $P^{3,4}$
($P^{l,m}$, l – number of levels of basic ordinal scale, m – number of labels)
(4,0,0)
(3,1,0)
(2,2,0)
(1,3,0)
(2,1,1)
(0,4,0)
(1,2,1)
(0,3,1)
(0,1,2)
(0,2,2)
(0,3,1)
(0,0,4)
A,B,C – 4 element (labels)

Evaluation (assessment): ordinal scale, scale based on multiset



Multiset coefficient (number of elements in scale based on multiset)



A,B,C – 4 element (labels)

Interval scale as multiset $P^{3,4}$
($P^{l,m}$, l – number of levels of basic ordinals scale or number of elements of the basic set,
m – number of labels or the number of elements of the multiset)

Formulae for multiset coefficient/ multiset number) as function in l, m

$$\frac{l\,(l+1)\,(l+2)\,\ldots\,(l+m-1)}{m\,!}$$

For l=3, m=4 :
the number of elements of the scale equals 15
(in the case of interval scale, it is less - 12)
For l=4, m=3: the number of elements in the scale equals 20

2.3.SCHEME 3: combinatorial synthesis (system design, design of system configuration)

METHODS:

1.Morphological analysis and its modifications

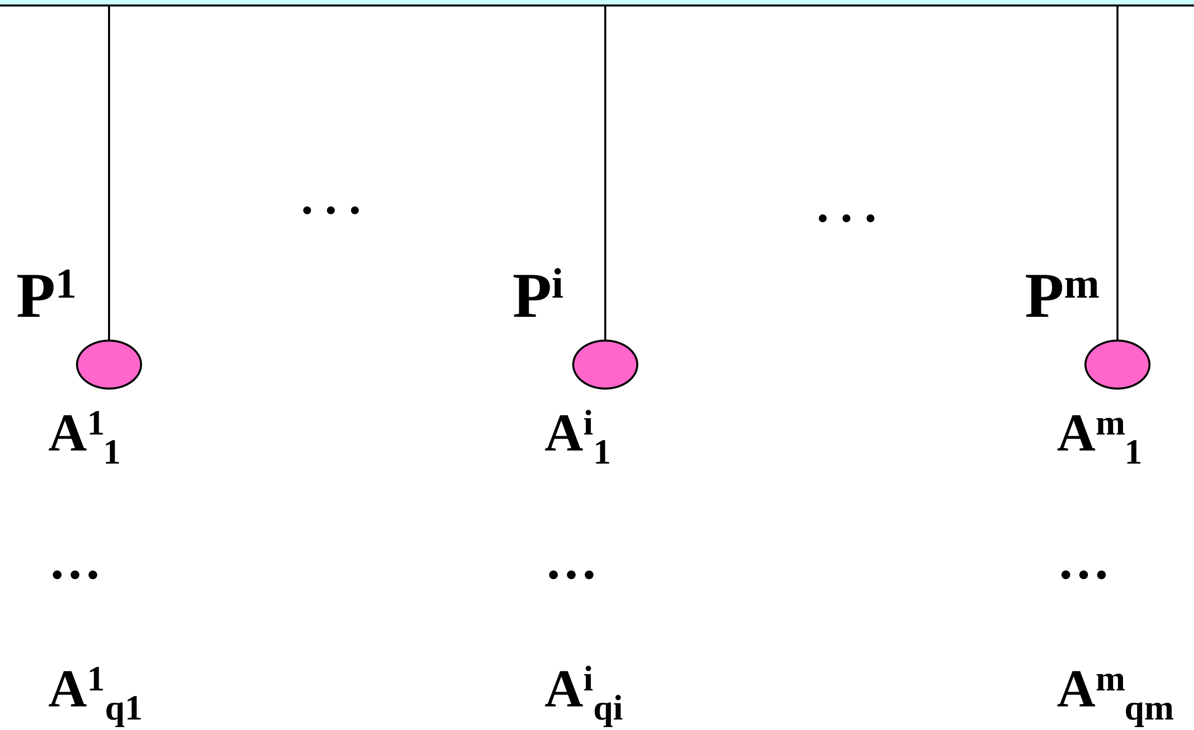
2.Hierarchical multicriteria morphological design (HMMD)
2.1. Basic version of HMMD
(ordinal estimates of design alternatives and compatibility)
2.2.HMMD with multiset estimates of design alternatives

3.Multiple choice problem
3.1.Basic multiple choice problem
3.2. Multiple choice problem with multiset estimates

Synthesis as multiple choice problem

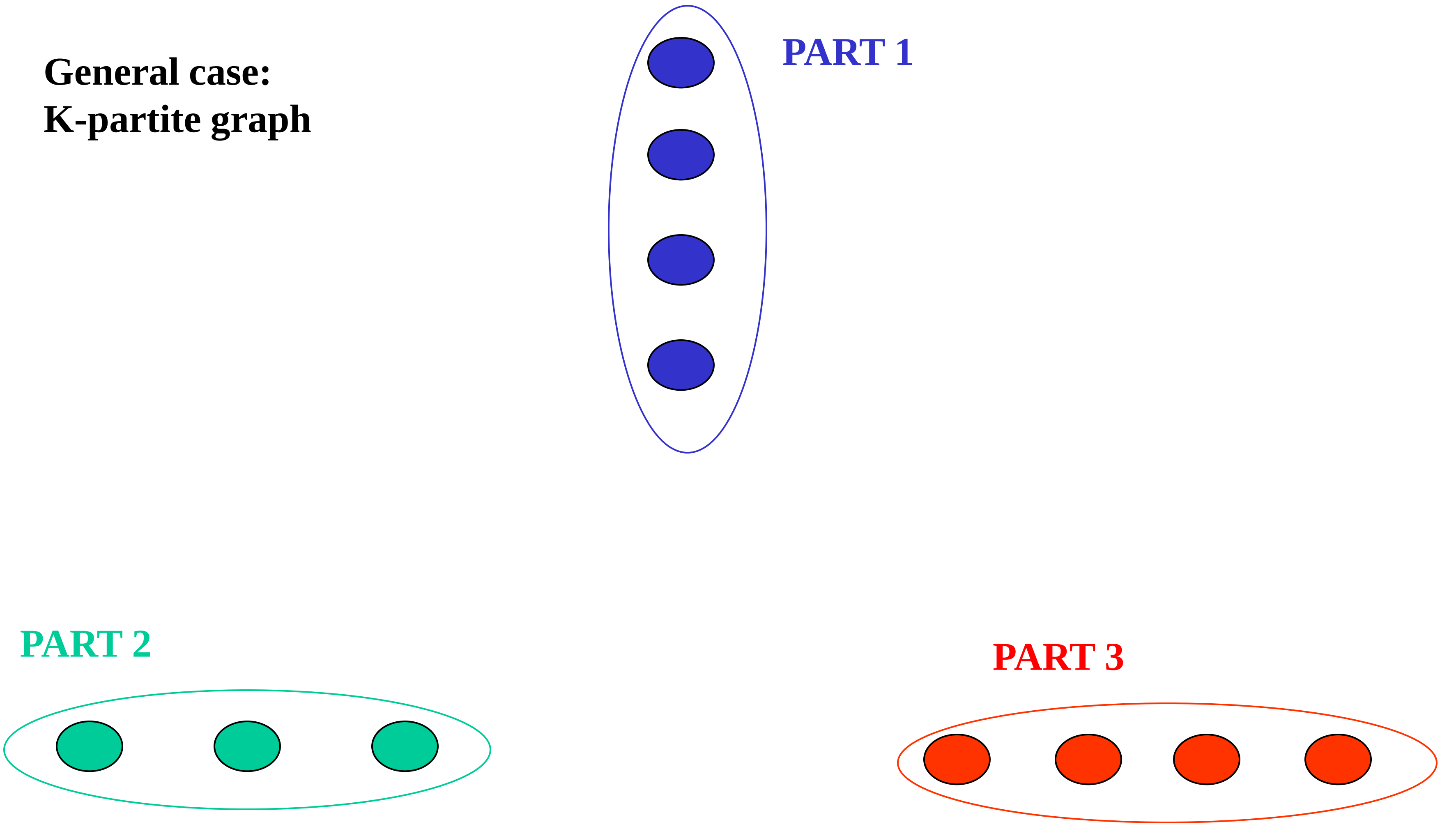
System $S = P^1 * \ldots * P^i * \ldots * P^m$

Solution example: $E_1 = A^1_3 * \ldots * A^i_2 * \ldots * A^m_1$

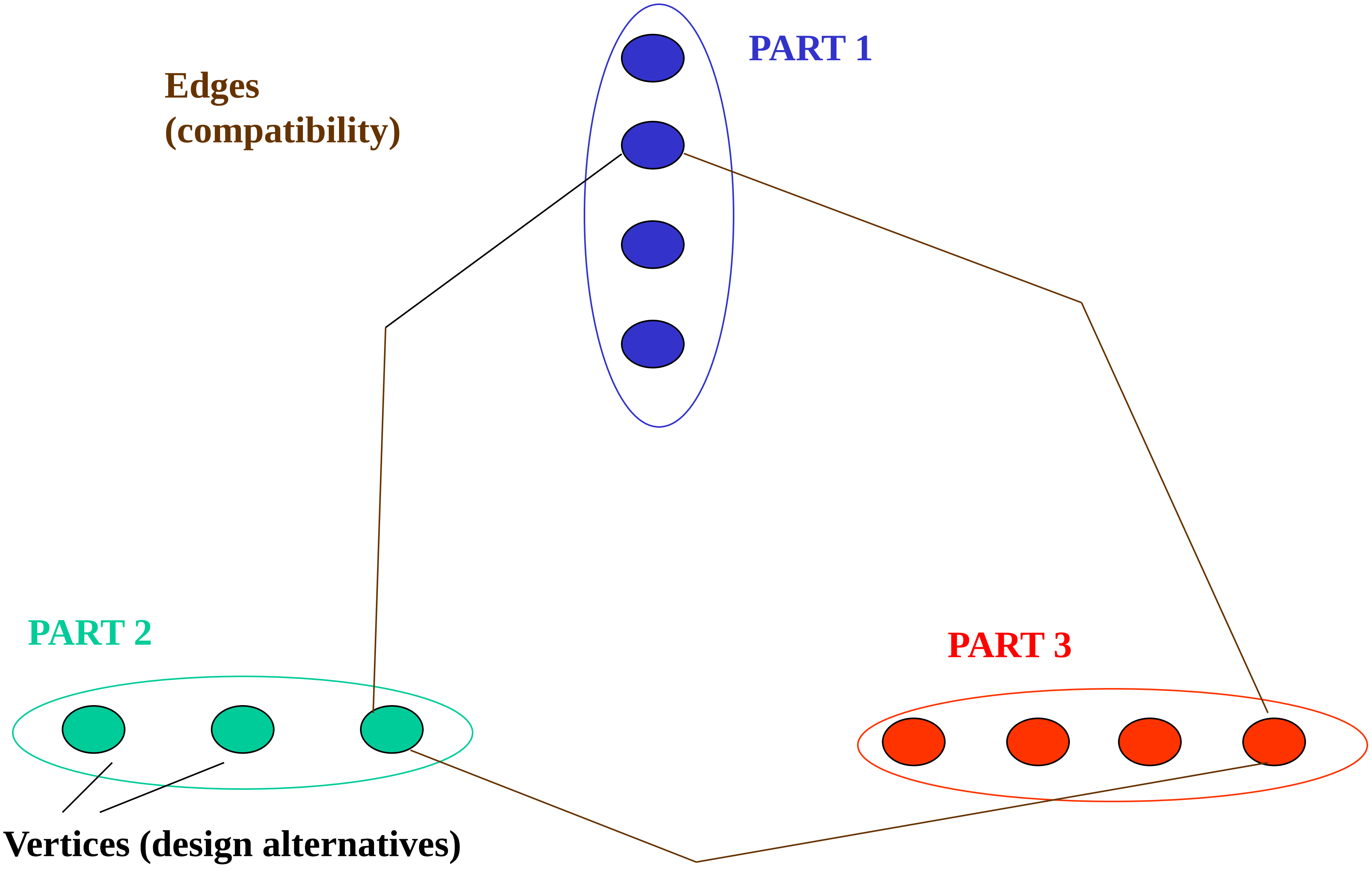


MORPHOLOGICAL CLIQUE

General case:
K-partite graph



MORPHOLOGICAL CLIQUE (multipartite graph)



MORPHOLOGICAL CLIQUE (multipartite graph): close models

Close combinatorial models:

1.Problem on representatives (Hall, 1930)
2.Problem of compatible representatives, binary relation over representatives-verticesKnuth, 1992)
3.Clustering in multipartite graph (2007…2008)
4.Maximal clique in multipartite graph (2001)
5.Coresets problem (2004…2011)
6.Transversals problems (design) (1971 …)

Close applied directions:

1.Morphological analysis and its modifications (Zwicky, 1943 …)
2.Design structure matrix based methods (1981-2008)
3.Method engineering (composition of methods/models in information systems) (1996…)
4.Morphological tables in management (1988)
5.OLAP – systems (information systems of high dimension) (1990 … now)
6.Mining association rules in large data systems (1993 …)
7.Combinatorial system testing (1996 …)

Basic design methods as morphological analysis and its modification/extension

1.Morphological analysis [F. Zwicky]

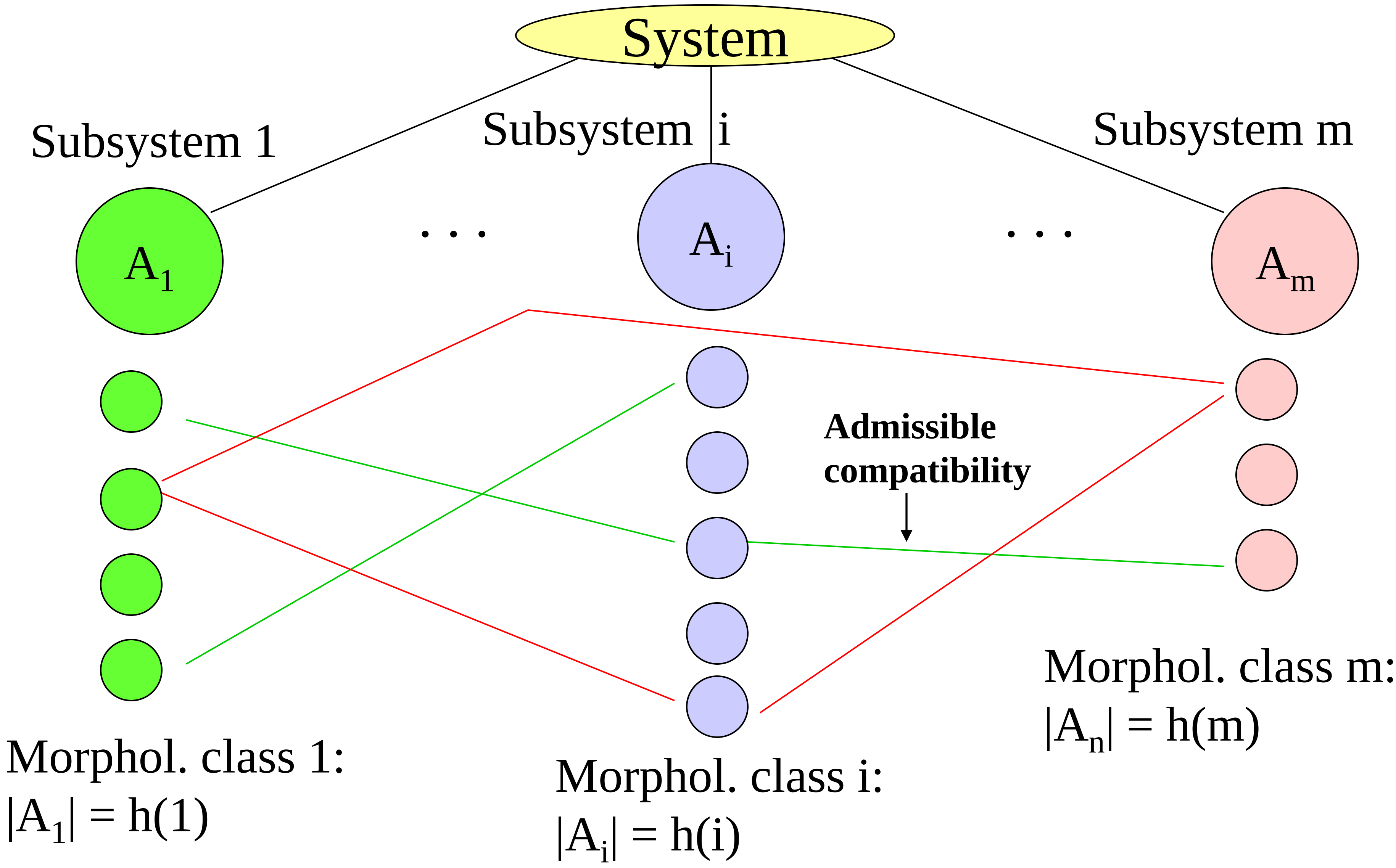
2.Proximity of admissible combinations to ideal (the best) [Ayres,1969; Iakimets, Moscow 1977]

3.Multicriteria estimates of admissible combinations and selection of Pareto-efficient solutions [Moscow, Inst. of Control Sciences, Inst. of Syst, Anal., etc., 1972/82]

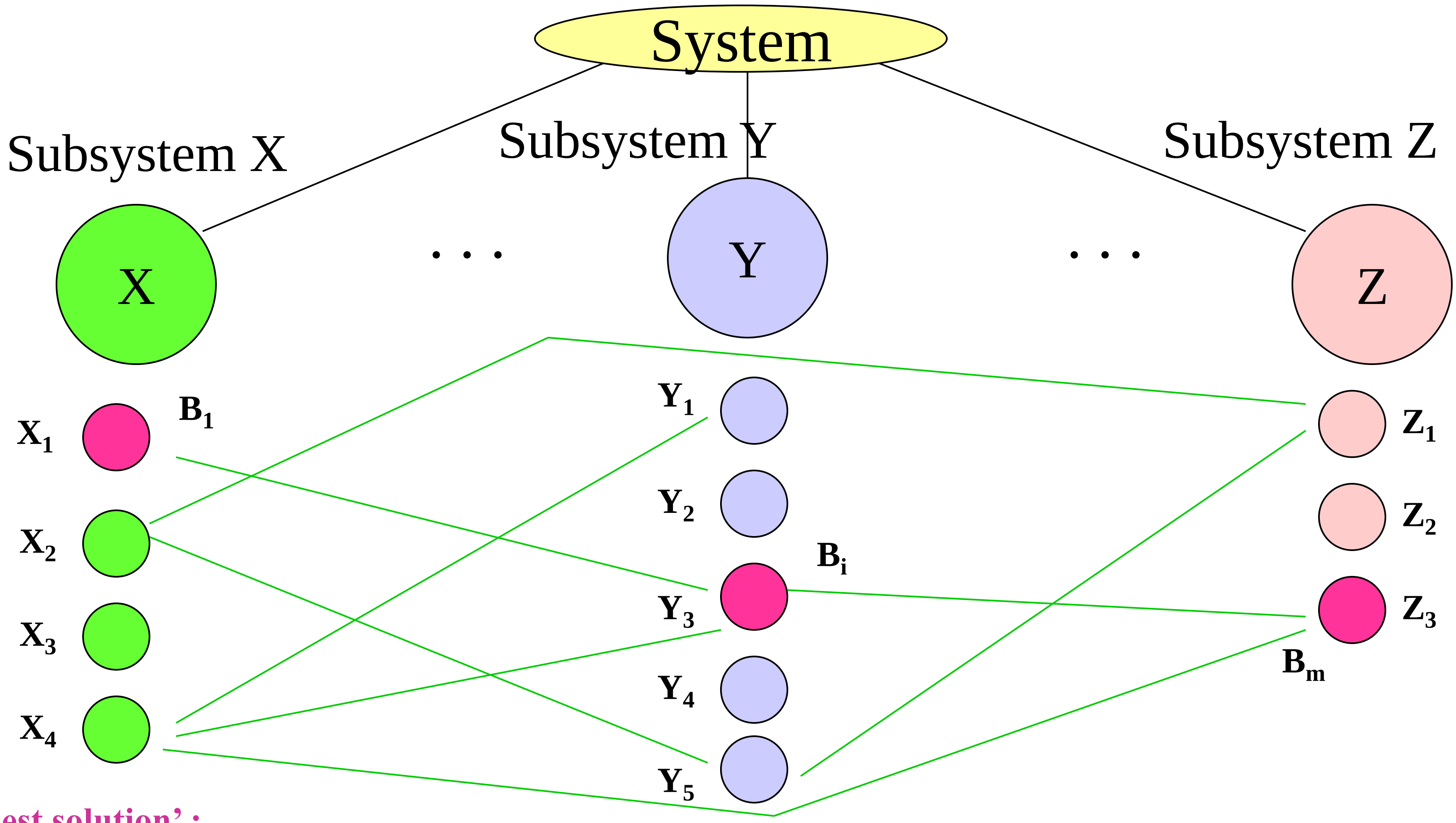
4.Hierarchical design (composition of local Pareto-optimal solutions[Krasnoshekov et al.,, Comput. Center, Moscow, 1979]

5.Hierarchical morphological design (combinatorial morphological synthesis, morphological clique) – HMMD [Levin, 1994…]

Morphological analysis



Morphological analysis: proximity to the best combination (Ayres, 1969)



'Best solution' :
$B = X_1 * Y_3 * Z_3$
(inadmissible combination)

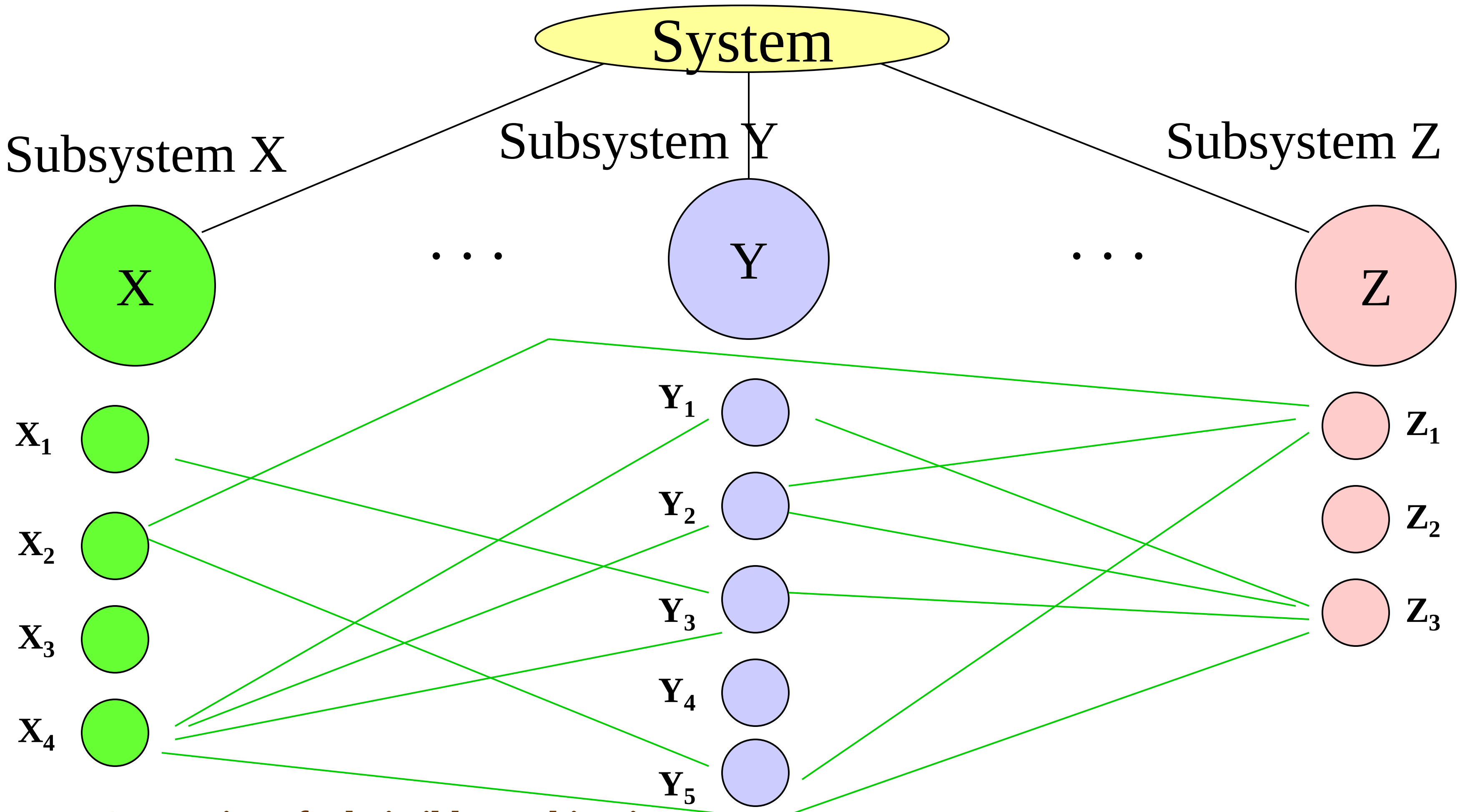
$S_1 = X_4 * Y_3 * Z_3$

$S_2 = X_2 * Y_5 * Z_1$

$\rho(B, S_1) < \rho(B, S_2)$

ρ - *proximity*

Multicriteria evaluation of admissible combinations & Pareto-based choice (1972..1982)



Phase 1. Generation of admissible combinations:

$S_1 = X_4 * Y_3 * Z_3$ $S_3 = X_4 * Y_2 * Z_3$

$S_2 = X_2 * Y_5 * Z_1$ $S_4 = X_4 * Y_1 * Z_3$

Phase 2. Assessment of combinations by criteria

Phase 3. Pareto-based choice

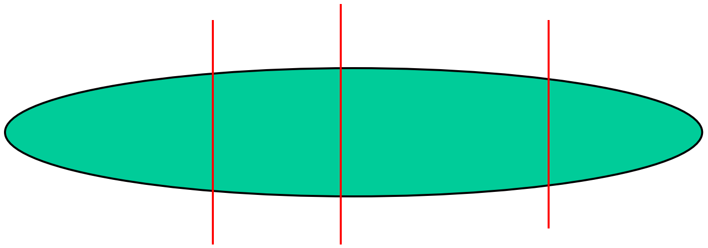
Morphological analysis

Complexity (by the number of initial combinations):

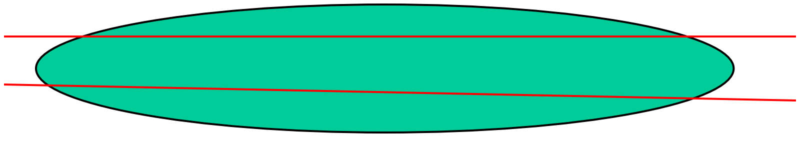
$h(1)*\ldots*h(i)*\ldots*h(m)$

Decreasing the complexity:

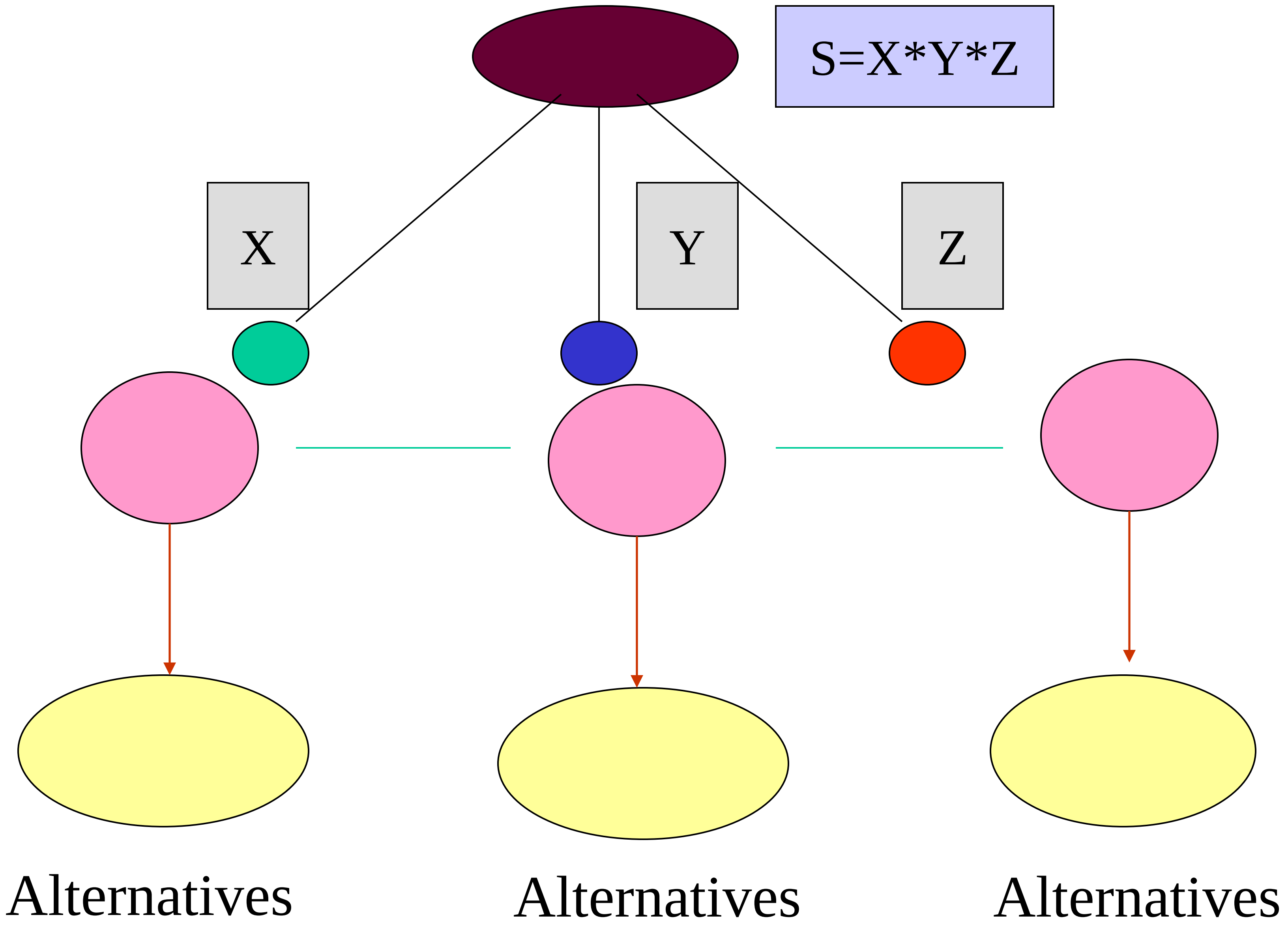
Horizontal partitioning (decomposition)



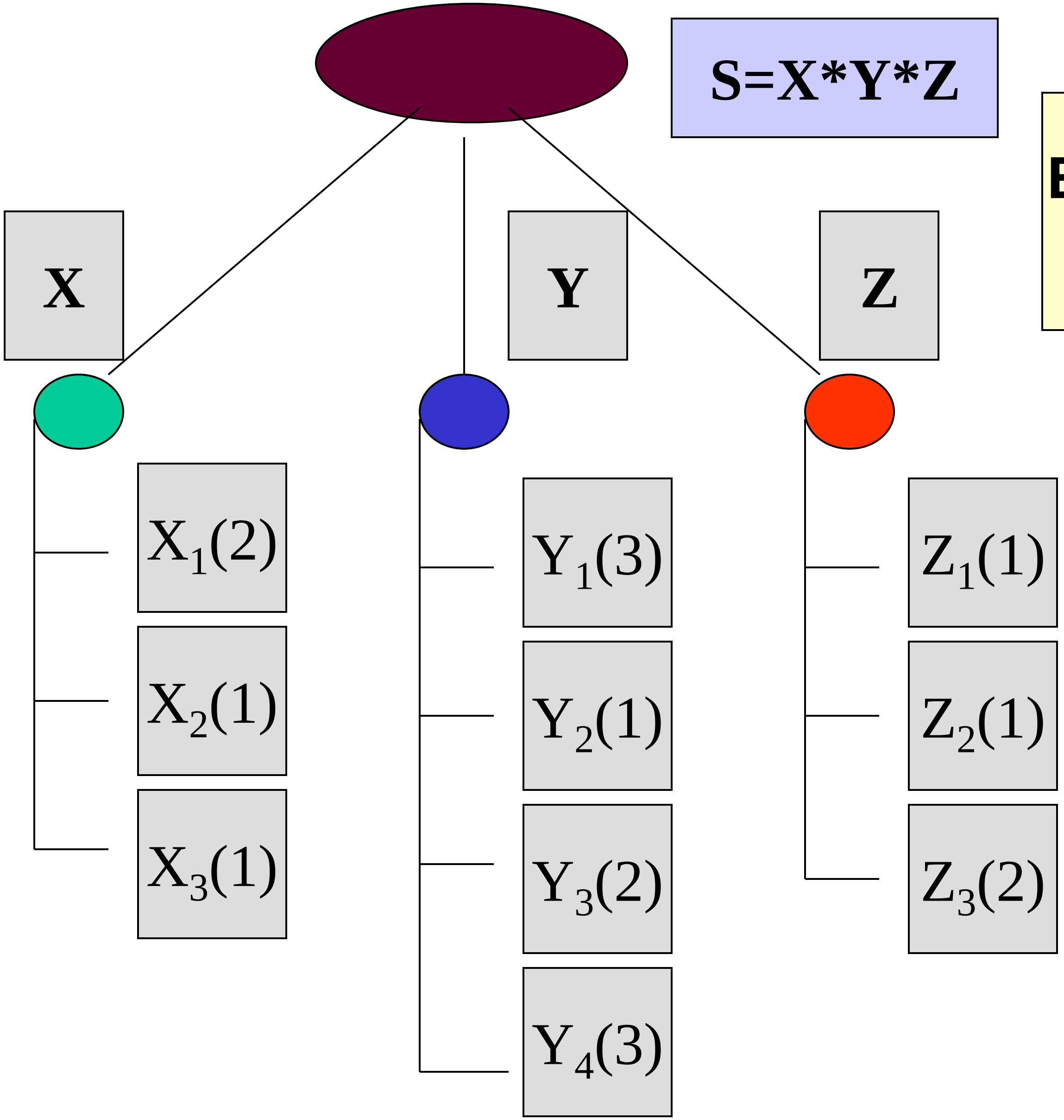
Vertical partitioning (decomposition)



Hierarchical design



Morphological combinatorial synthesis: illustrative numerical example



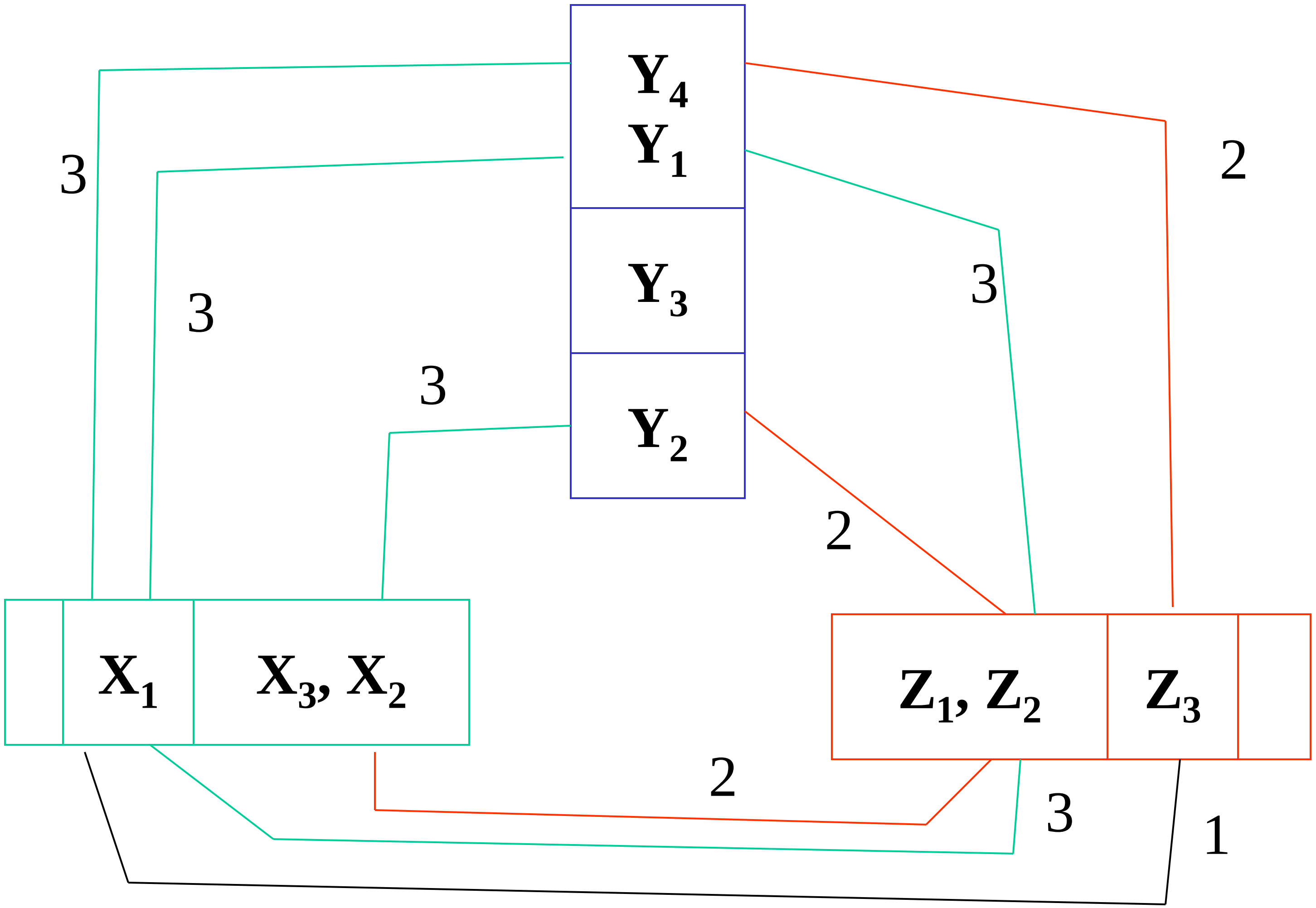
Example of solution:

$S_a = X_1 * Y_4 * Z_3$

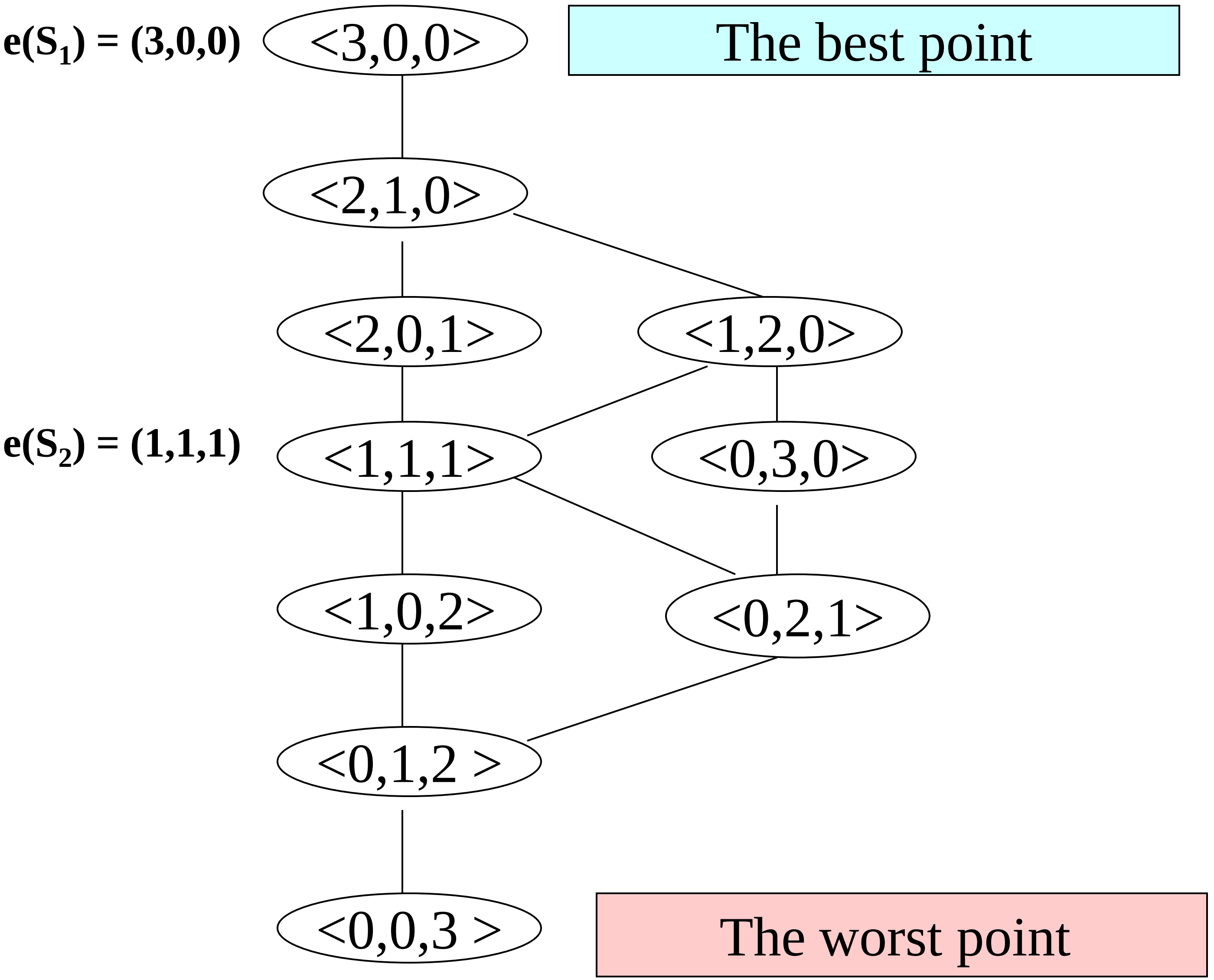
Concentric presentation of morphological clique with compatibility estimates

$S_1 = X_2*Y_2*Z_2$ $N(S_1) = (2;3,0,0)$

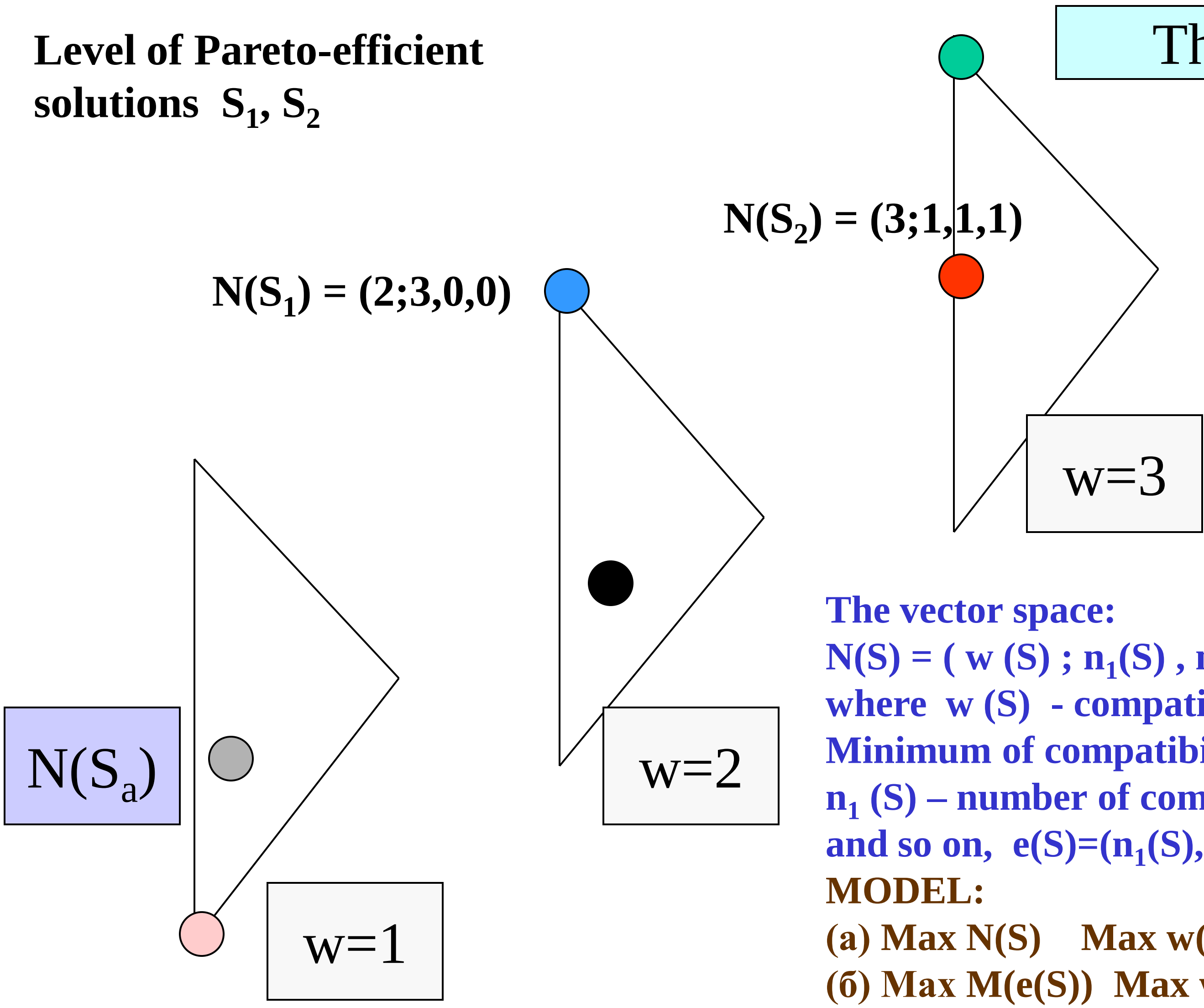
$S_2 = X_1*Y_1*Z_2$ $N(S_2) = (3;1,1,1)$



Discrete domain of system combination quality (by elements)



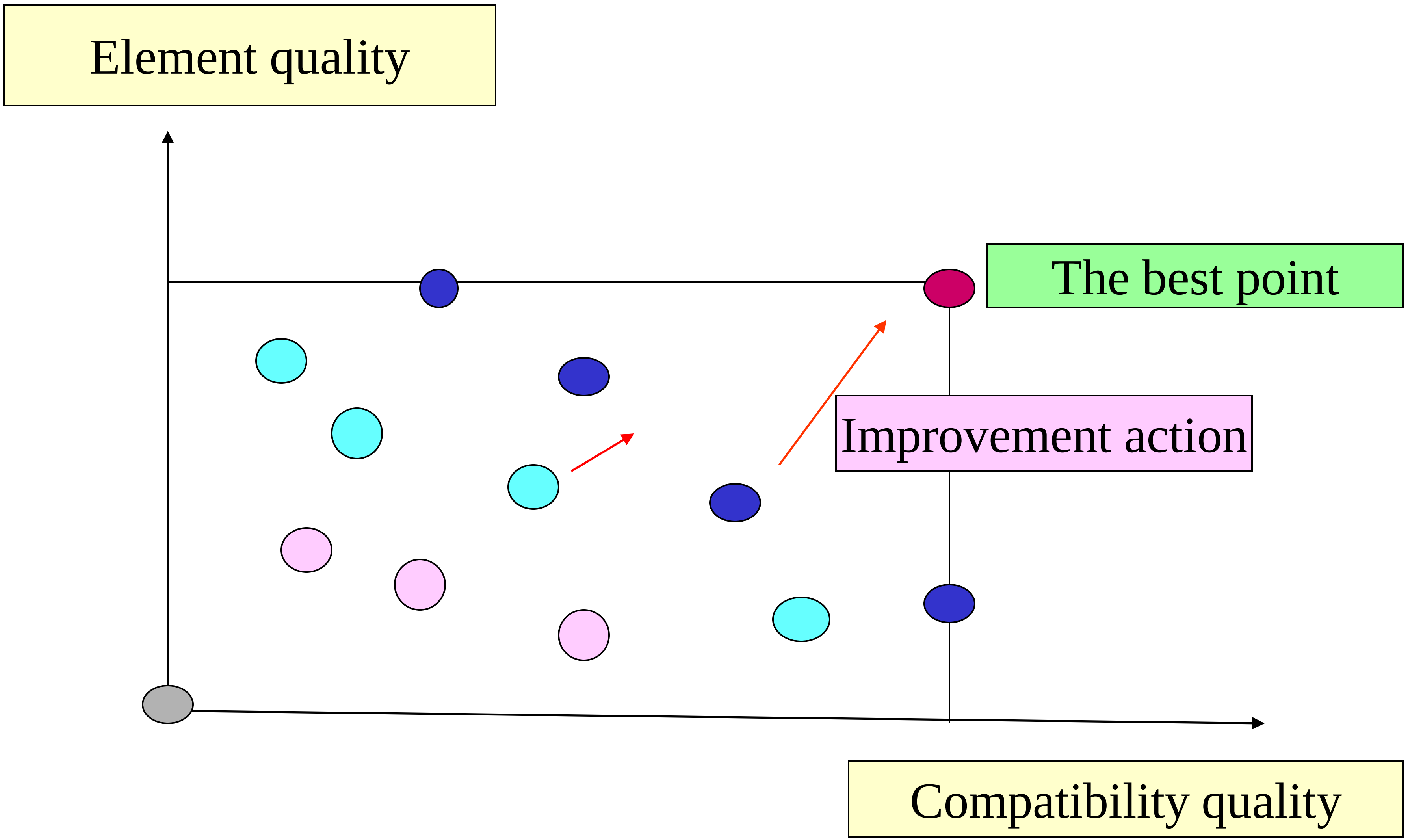
Discrete domain of system combination quality (by elements, by compatibility)



The vector space:
$N(S) = (w (S) ; n_1(S) , n_2(S) , n_3(S))$
where w (S) - compatibility estimate, i.e.,
Minimum of compatibility estimate for pair,
n_1 (S) – number of components at level quality 1
and so on, $e(S)=(n_1(S),n_2(S),n_3(S))$

MODEL:
(a) Max N(S) Max w(S) s.t. w(S) > 0
(б) Max M(e(S)) Max w(S) s.t. w(S) > 0
(M – median, in the case on interval multiset estimates)

Two-criteria quality domain: generalized scale and improvement actions/operations

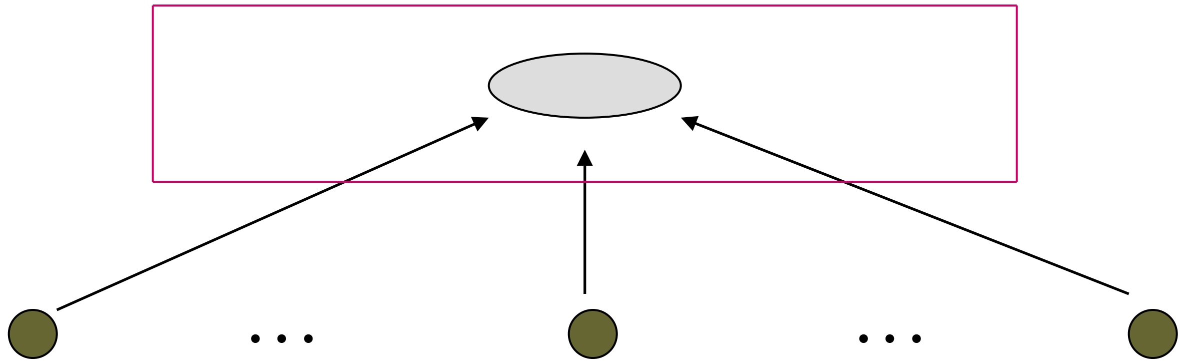


Two types of solving procedures

1.Enumerative directed heuristic as analysis and testing (beginning since the best point)

2.Dynamic programming procedure (as an extended version of procedure(s) for knapsack problem or multiple choice problem

Knapsack problem



1	i	m	(index)
a_1	a_i	a_m	(required resource)
c_1	c_i	c_m	(profit/utility)
x_1	x_i	x_m	(Boolean variable)

$$\max \quad \sum_{i=1}^{m} c_i \; x_i$$

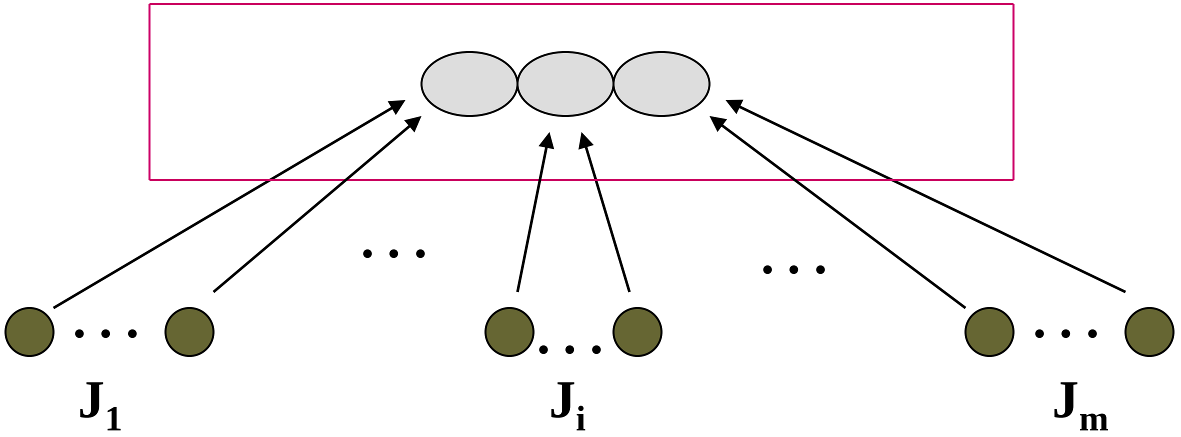
$$s.t. \quad \sum_{i=1}^{m} a_i \; x_i \leq b$$

$$x_i \in \{0, 1\}, \; i = 1, \ldots, m$$

Possible additional constraints

$$\sum_{i=1}^{m} a_{ik} \; x_i \leq b_k \; , \; k = 1, \ldots, l$$

Multiple choice problem



$$\forall\ i \quad |J_i| = q_i\ ,\ \ j = 1, \ldots, q_i$$

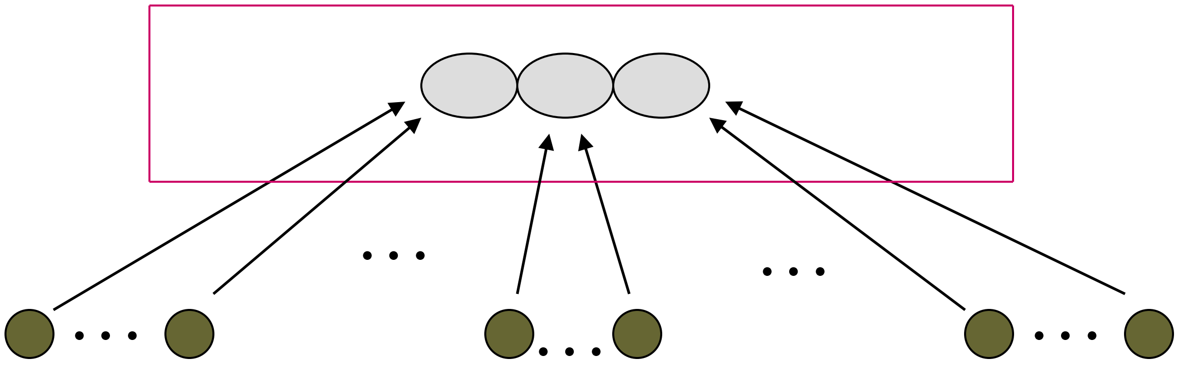
$$\mathit{max} \quad \sum\nolimits^{m}_{i=1} \ \sum\nolimits^{qi}_{j=1} \ c_{ij}\ x_{ij}$$

$$\mathit{s.t.} \quad \sum\nolimits^{m}_{i=1} \sum\nolimits^{qi}_{j=1} a_{ij}\ \ x_{ij} \ \le \ \ b$$

$$\sum\nolimits^{qi}_{j=1}\ x_{ij} \ \le \ \ 1\ , \quad i = 1, \ldots, m$$

$$x_{ij} \in \ \{0, 1\}, \quad i = 1, \ldots, m\ , \quad j = 1, \ldots, q_i$$

Многокритериальный блочный рюкзак



$$\forall\ i \quad |\, J_i \,| \ = \ q_i \,,\ \ j = 1, \dots, q_i$$

$$c_{ij} \ \Rightarrow (\, c^1_{ij} , \dots , c^p_{ij} , \dots , c^k_{ij} \,)$$

$$(\, \sum^m_{i=1} \sum^{qi}_{j=1} \ c^1_{ij} \ x_{ij} , \dots , \sum^m_{i=1} \sum^{qi}_{j=1} c^p_{ij} \ x_{ij} , \dots , \sum^m_{i=1} \sum^{qi}_{j=1} \ c^k_{ij} \ x_{ij} \,) \ \ ->$$

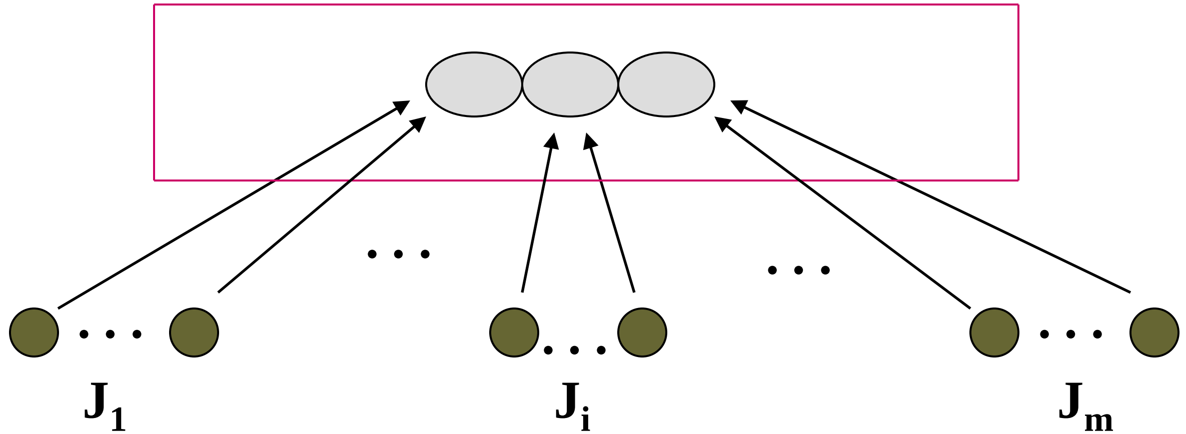
Pareto-efficient solutions

s.t. $\sum^m_{i=1} \sum^{qi}_{j=1} a_{ij} \ \ x_{ij} \ \le \ \ b$

$$\sum^{qi}_{j=1} \ x_{ij} \ \le \ \ 1 \,, \ \ i = 1, \dots, m$$

$$x_{ij} \in \ \{0, 1\}, \ \ i = 1, \dots , m \,, \ \ j = 1, \dots, q_i$$

Multiple choice problem with multiset estimates (median-solution)



$\forall\ i \quad |J_i| = q_i , \ j = 1, \ldots , q_i$

c_{ij} => e_{ij} (interval multiset-based estimates, e.g., $e_{ij} = (3,1,0)$)

$\max M (\{e_{ij}\}) = \arg\min_{\{M\}} \ \sum^{m}_{i=1} \ d (M,e_{ij})$

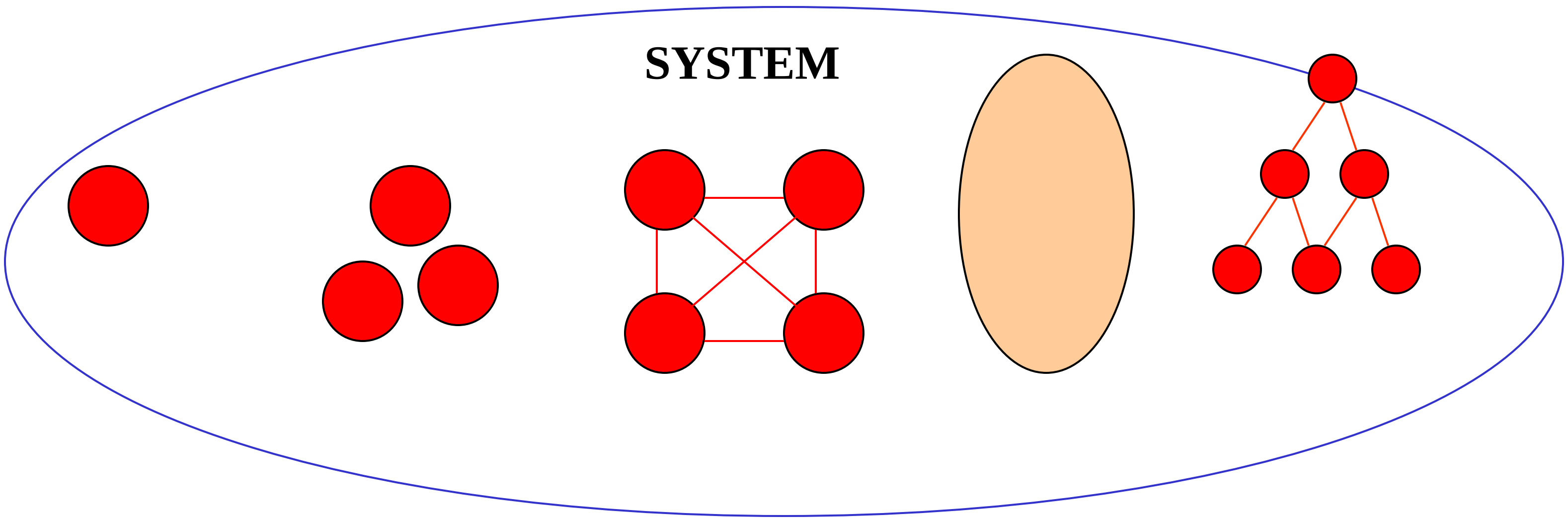
(d – measure of 'proximity'/distance, M – median of estimates by selected elements of Pareto-efficient solutions)

s.t. $\quad \sum^{m}_{i=1} \sum^{qi}_{j=1} a_{ij} \ x_{ij} \leq \ b, \qquad \sum^{qi}_{j=1} \ x_{ij} \leq \ 1 , \ \ i = 1, \ldots, m$

$x_{ij} \in \{0, 1\}, \ \ i = 1, \ldots , m , \ \ j = 1, \ldots, q_i$

2.4.Scheme 4: Detection of bottlenecks

System bottlenecks:
1.Element of element relationship (connection)
2.Group of elements
3.Group of interconnected elements
4. System structure
5.Dynamical problems (online mode, forecast)



2.4.Scheme 4: Methods for detection of bottlenecks

METHODS:

1.Traditional approach (quality management):
(a) Pareto-method (detection of elements with the worst reliability estimate(s))
(b) multicriteria ranking of system elements

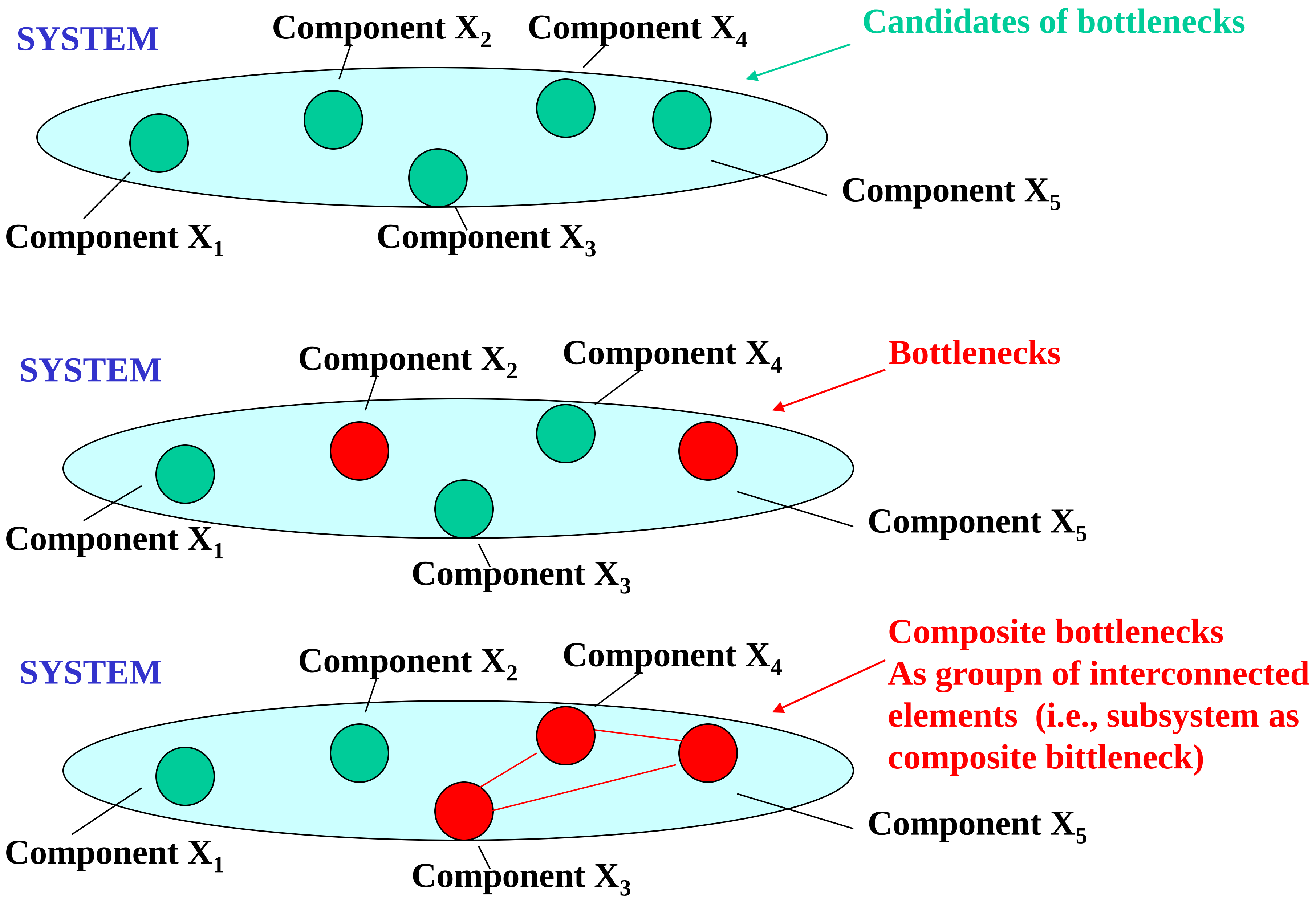
2.Bottlenecks in HMMD (searching for the elements or element compatibility when their improvement will lead to essential improvement of the system quality)

3.Critical node in networks (e.g., spanning tree with maximal number of terminals, connected dominated set)

4.Detection of interconnected system components (i.e., subsystems consisting of interconnected elements) - HMMDB

5.Information fusion based on clique over graph streams

2.4.Illustration for detection of system bottlenecks



Trajectory (states) for element, subsystem, intersection of two subsystems

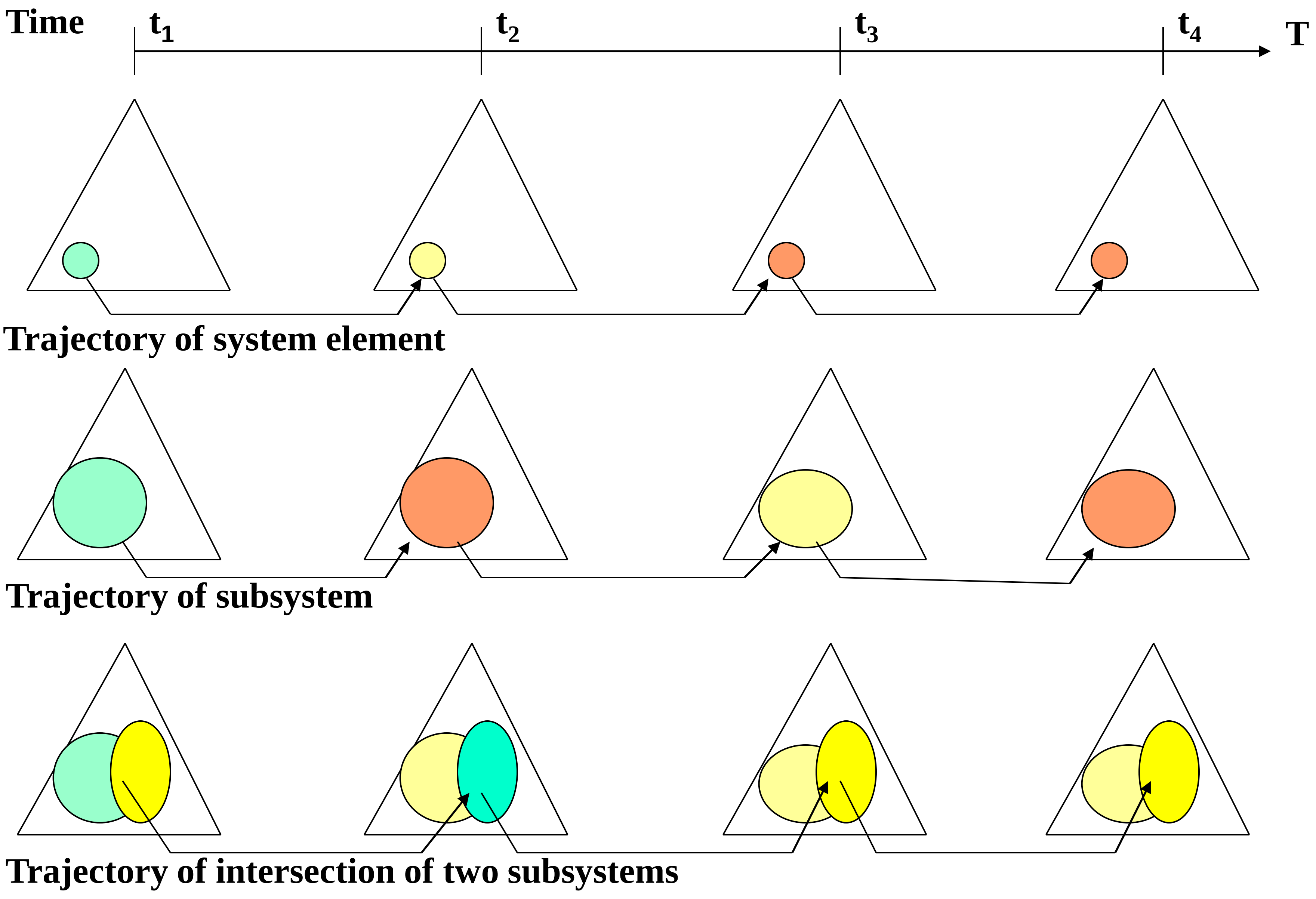


Illustration for detection of clique over graph streams

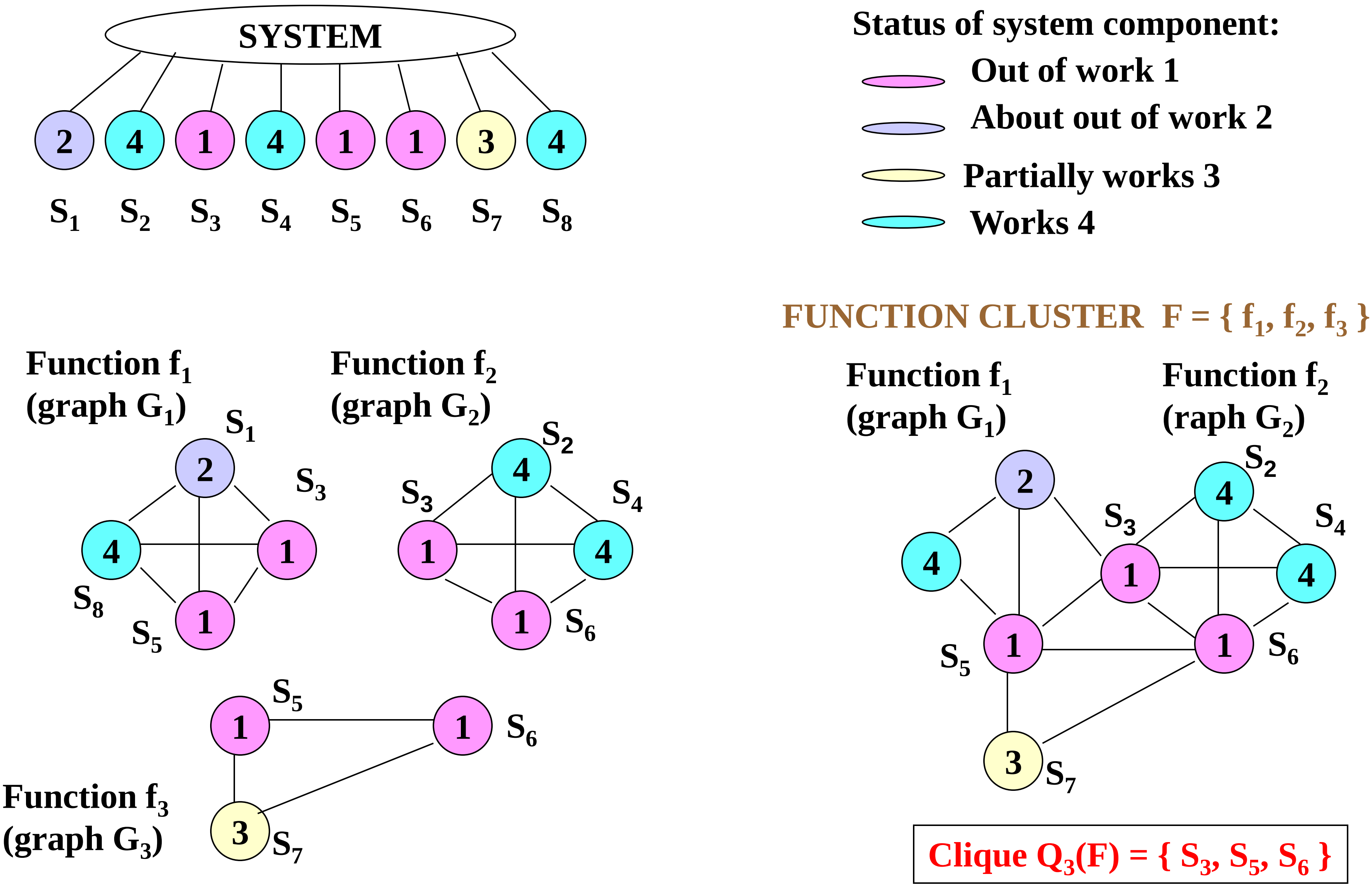
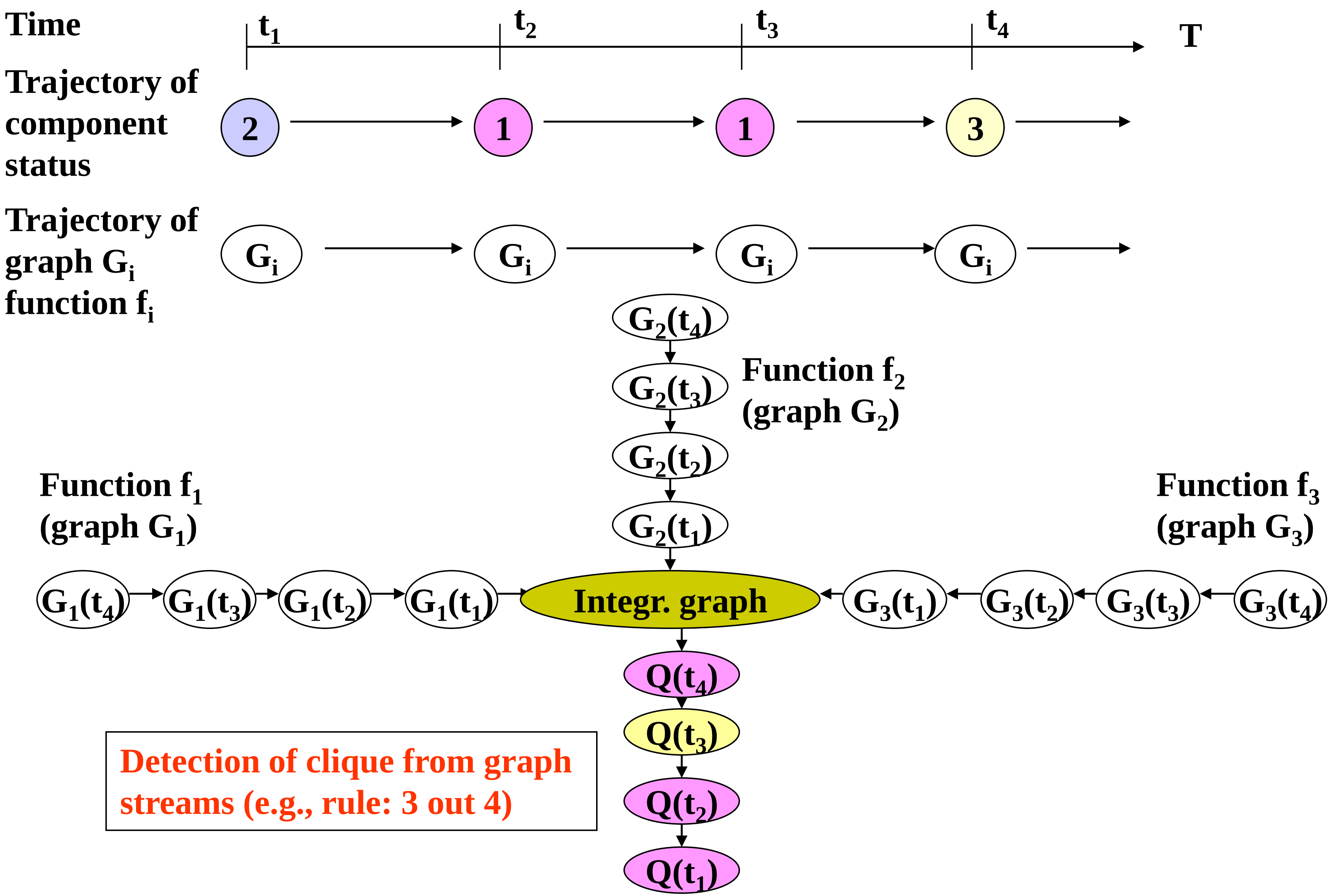


Illustration for detection of clique over graph streams



2.5.SCHEME 5: System improvement, extension

BASIC SUTUATIONS OF SYSTEM IMPROVEMNT:

1.Improvement by system components:
1.1.Multiple choice problem 1.2.HMMD

2.Improvement (modification) of system structure:
(a)modification of tree (i.e., tree-like system structure)
(b)Transformation of tree into
(c)Assignment of 'hot-links' (special combinatorial problem)
(d)Augmentation of tree problem
(e)Augmentation of graph/network

3.System extension (addition of an additional system part)

4.Aggregation of system solutions: (i) 1 final aggregated solution, k final aggregated solutions (here- special SCHEME)

5.Approaches in combinatorial optimization:
(a)reoptimization ,
(b)restructuring

2.5.General change operations

Typical change operations:

I.For DA's:

1.1.Change / improvement of DA's O_1: $A_i \Rightarrow A'_i$
1.2.Deletion DA O_2
1.3.Addition DA O_3
1.4.Aggregation DA's O_4: $\{A_i\} \Rightarrow A^a = A_1 \& A_2 \& \ldots$
1.5.Standardization DA's O_5: $\{A_i\} \Rightarrow A^s$

II.Change operations for subsystems (system parts):

2.1.Change / improvement of system part O_6
2.2.Deletion O_7
2.3.Addition O_8
2.4.Aggregation O_9

2.5.Description of change process

I.Characteristics/parameters of change operations:

1.Required resource (e.g., cost)
2.Possible profit (utility)
3.Ect.

II.Binary relations over operations:

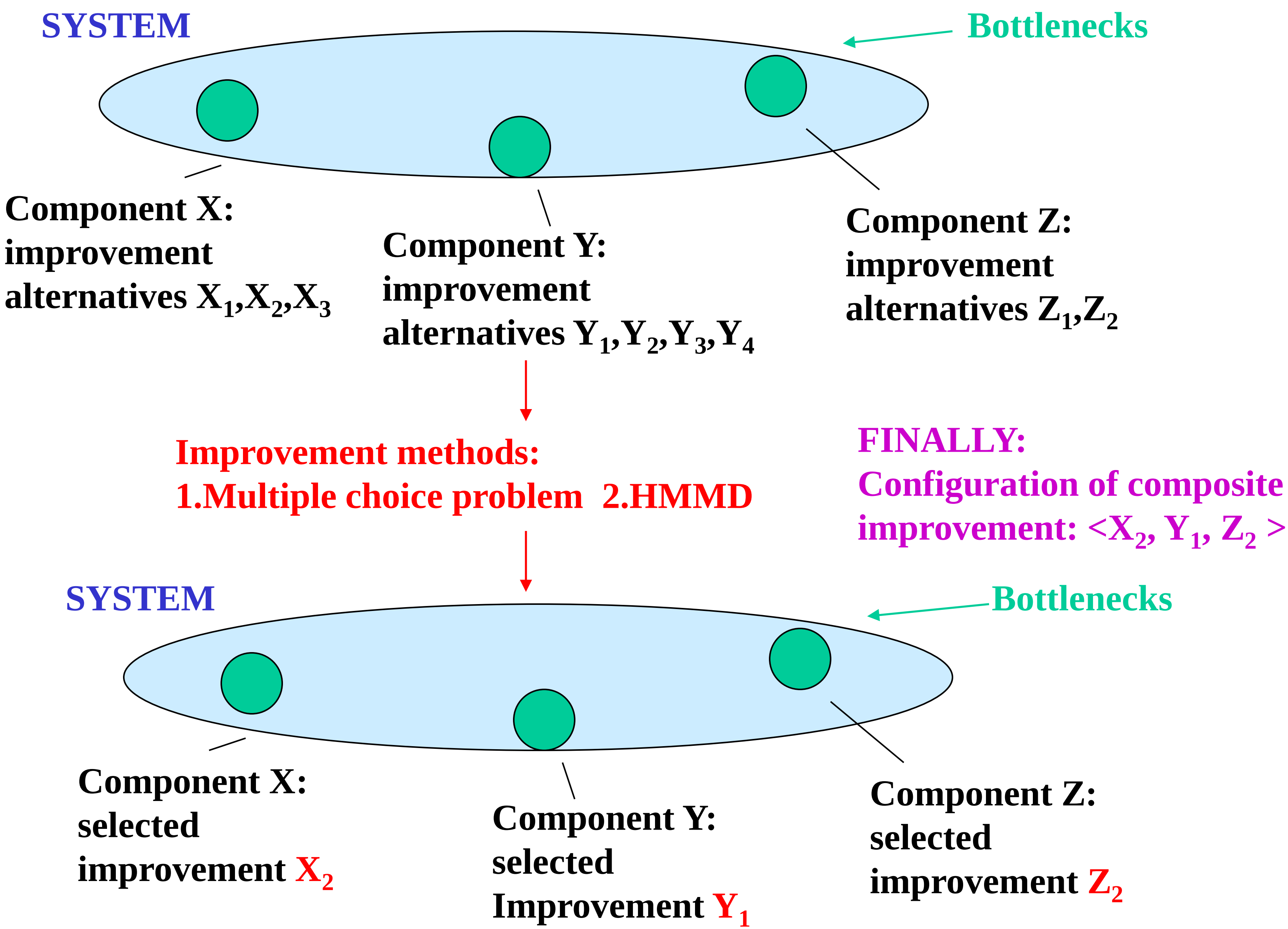
1.Precedence (O_i => O_j)
2.Equivalence
3.Complementarity

Combinatorial problems:

- 1.Multicriteria ranking (e.g., for change operations)
- 2.Knaspack (selection of change operations)
- 3.Multiple choice problem (selection of change operations)
- 4.Multicriteria knapsack (selection of change operations)
- 5.Multicriteria multiple choice problem (selection of change operations)

6.Planning (scheduling) (scheduling of the change operations)
7.HMMD (synthesis of composite change actions consisting of change operations)

Illustration for improvement by system components



Improvement and modification of system structure/architecture (i.e., topology)

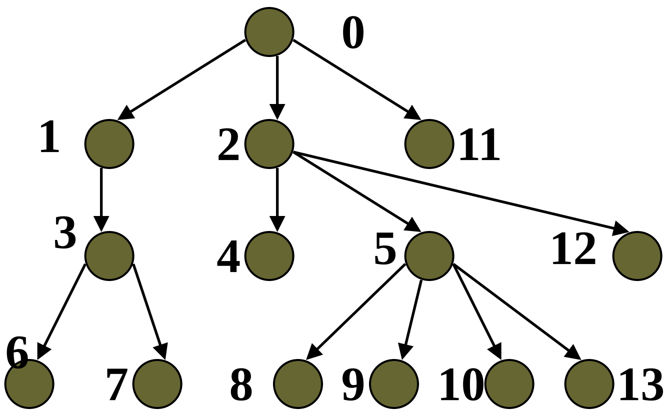
Initial topology (tree, network)

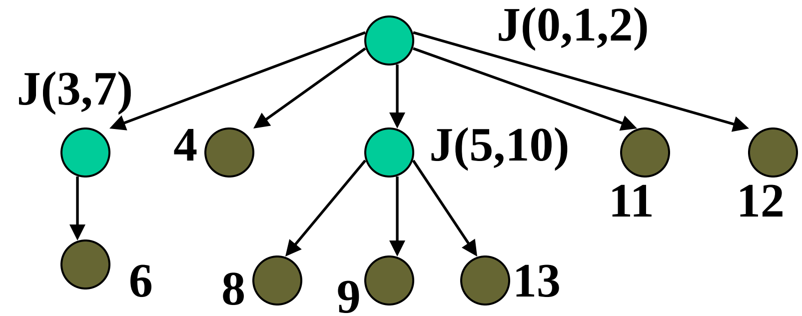
Resultant topology

OPERATONS:
***addition of edges/arcs (links),**
***deletion of edges/arcs (links),**
***addition vertices (nodes),**
***deletion of vertices (nodes),**
***integration of vertices (nodes) (condensation)**

MODELS:
1.Graph augmentation problem
2.Multiple choice problem
3.Special transformation of tree (e.g., node integration-condensation) (e.g., design of over-lay structure for tree-like software)
4.Hotlink assignment
5.HMMD

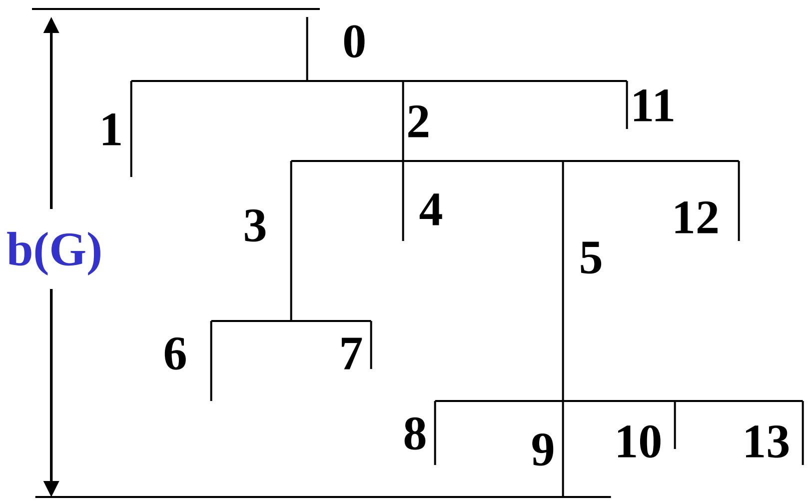
Modification of software tree: over-lay structure (example) [Levin, 1981]

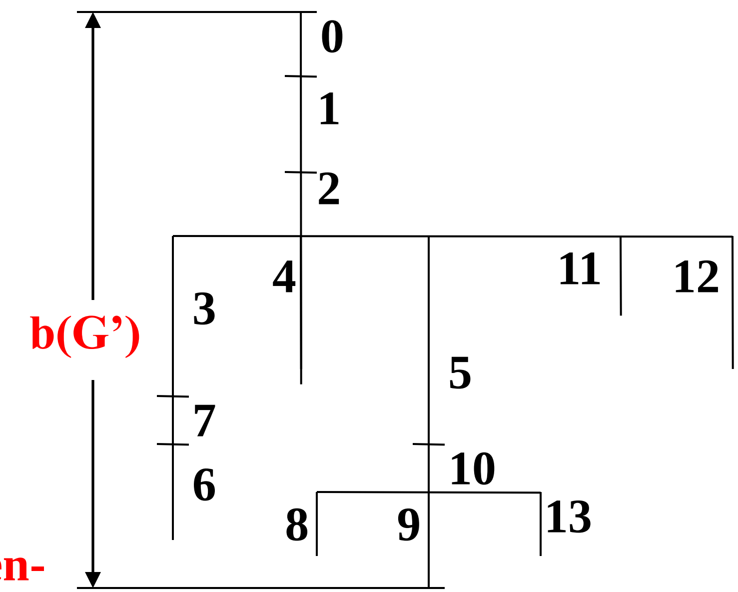




Software tree G=(A,E), arc weight $c(a_i,a_j)$ – frequency of call, vertex weight $b(a_i)$ – required operative memory

b(G) – maximum of path length from root to leaf vertex (sum of vertices weights by path)

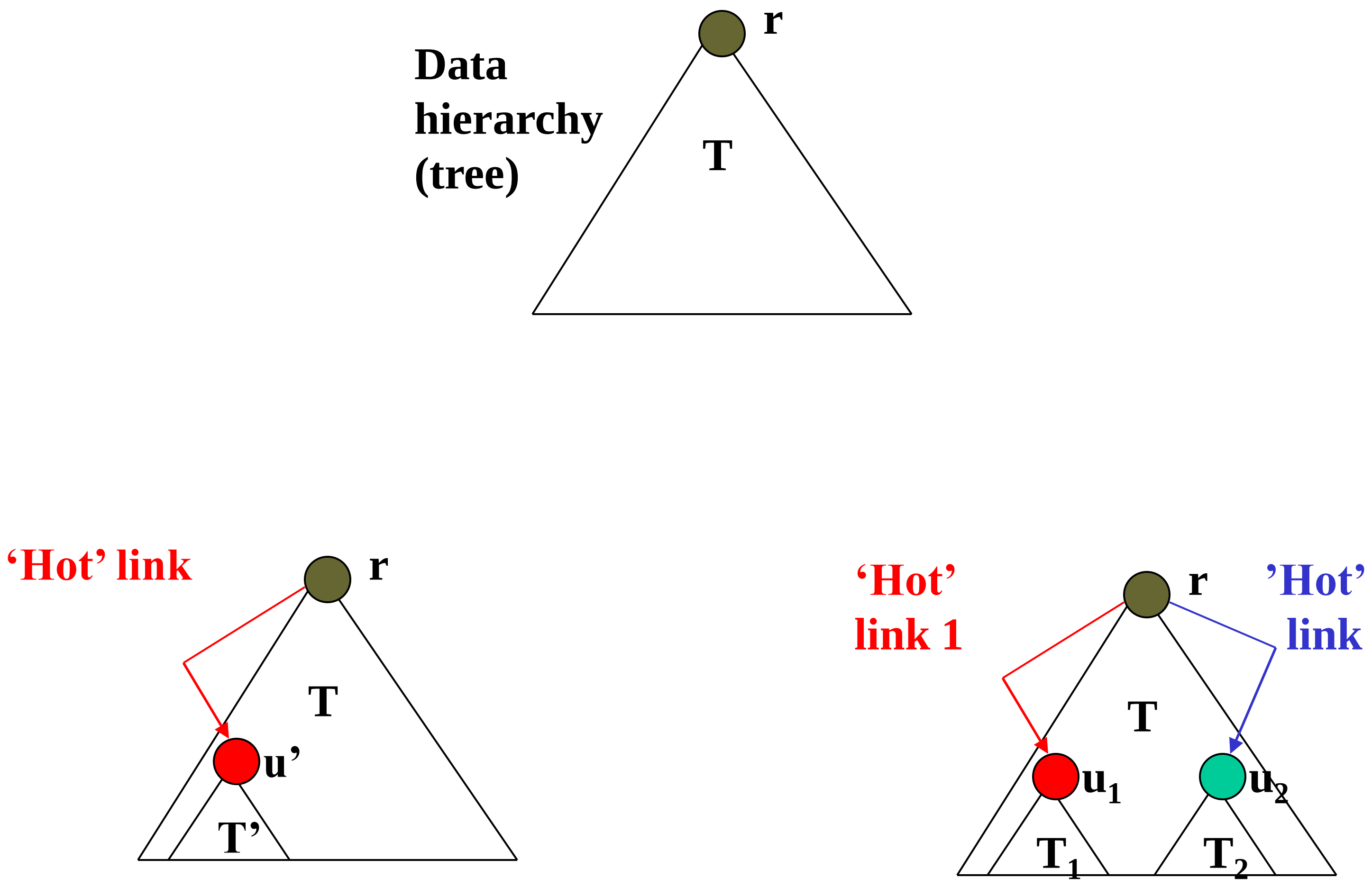




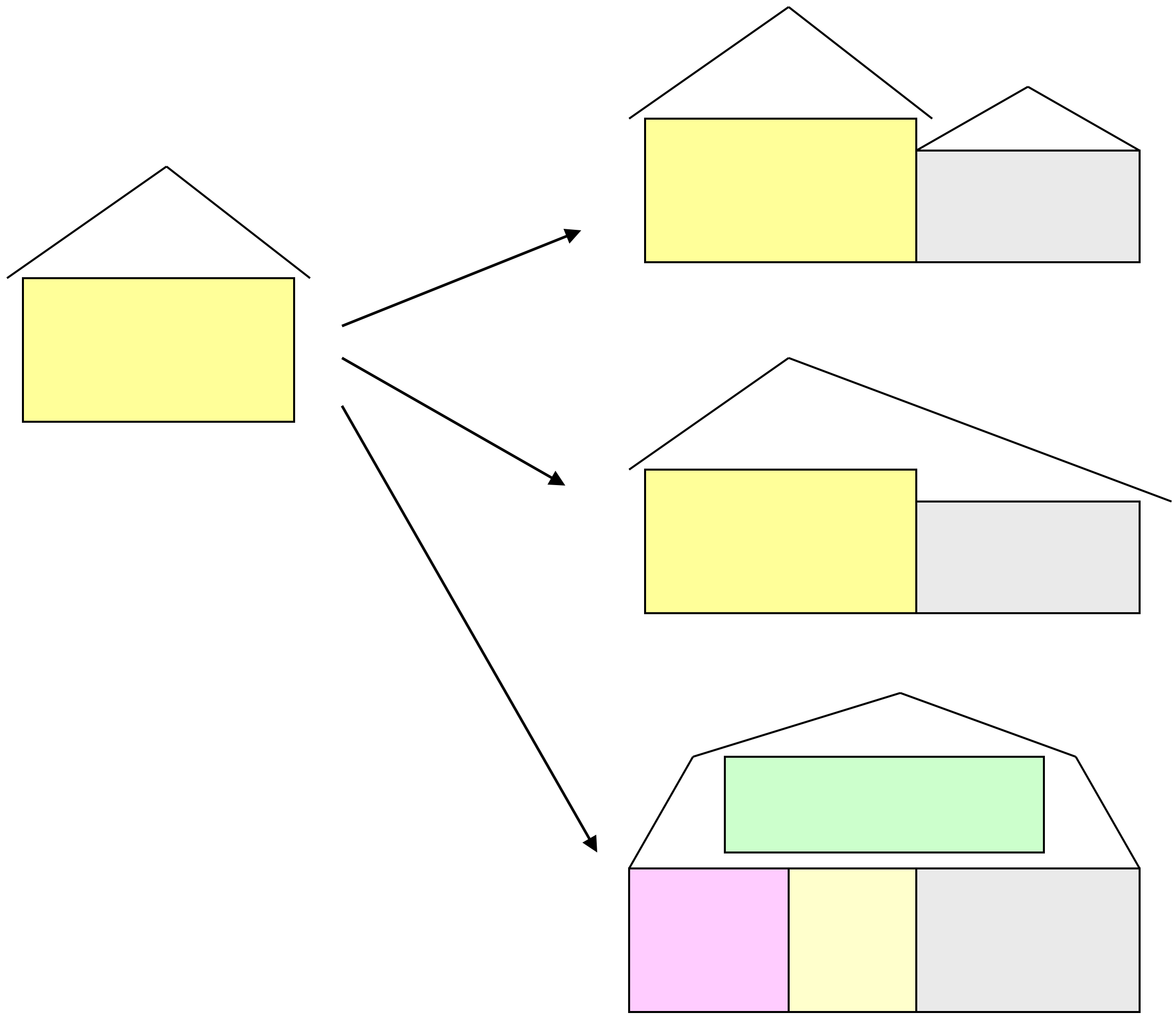
PROBLEM: Max of weigth sum for deleted by conden-sation) arcs s.t. b(G') <= b, b – constraint by the required volume of operative memory

Complexity (PTAS): $O(n^7 / e d^4)$, n = | A |, e -relative error by goal function, d– relative error by constraint

Modification of data tree: hot—link assignment problem



System extension



Method 1. Addition

**Method 2.
Coordinated addition**

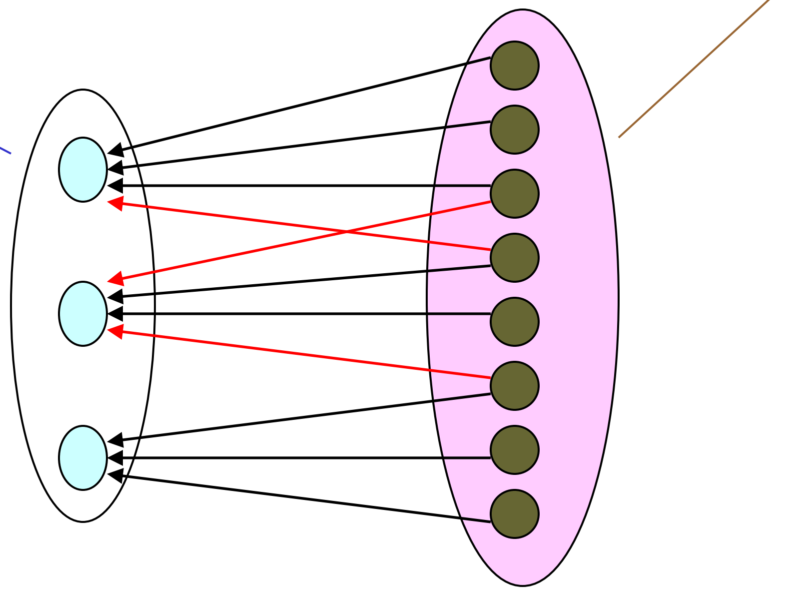
**Method 3.
New design**

Example: extension of network (allocation of user to access points – assignment problem) [Levin, 2010]

Problem:

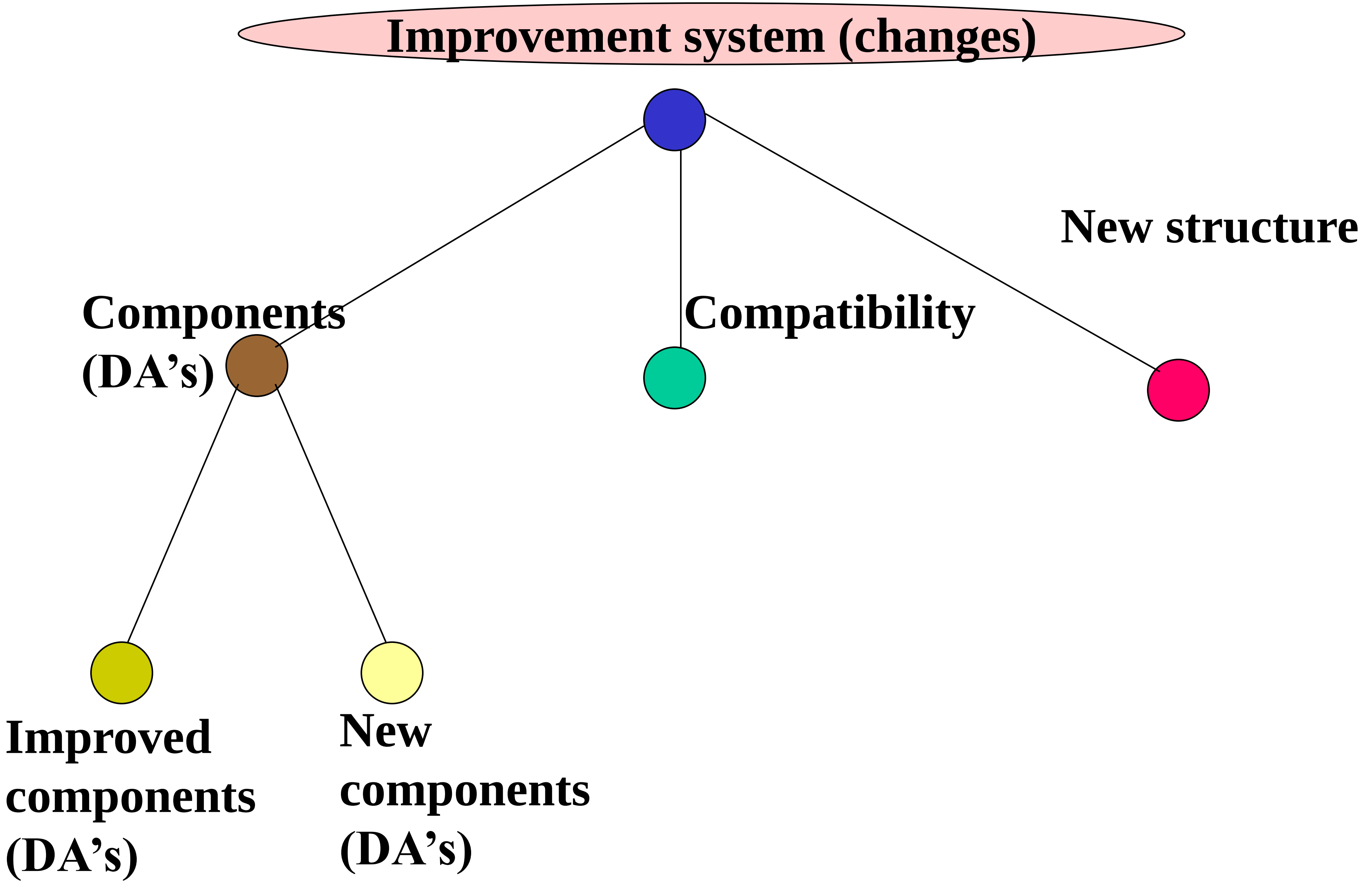
1.Access points **2.End (terminal) users**

PROBLEM:
Allocate of users to access point



1.Multicriteria assignment problem: allocation of each end users to the only one access point
2.Generalized multicriteria assignment problem (resource constraints for access points)
3.Generalized multicriteria assigment problem: allocation of each end users to several access points.

Improvement system-general glance



1.Reoptimization. Given solution for combinatorial optimization problem (e.g., minimum spanning tree, minimum Steiner tree, TSP, covering, minimum common subsequence). Problem: Find and improvement of the solution by small changes (addition of vertex, deletion of vertex) [2008…]

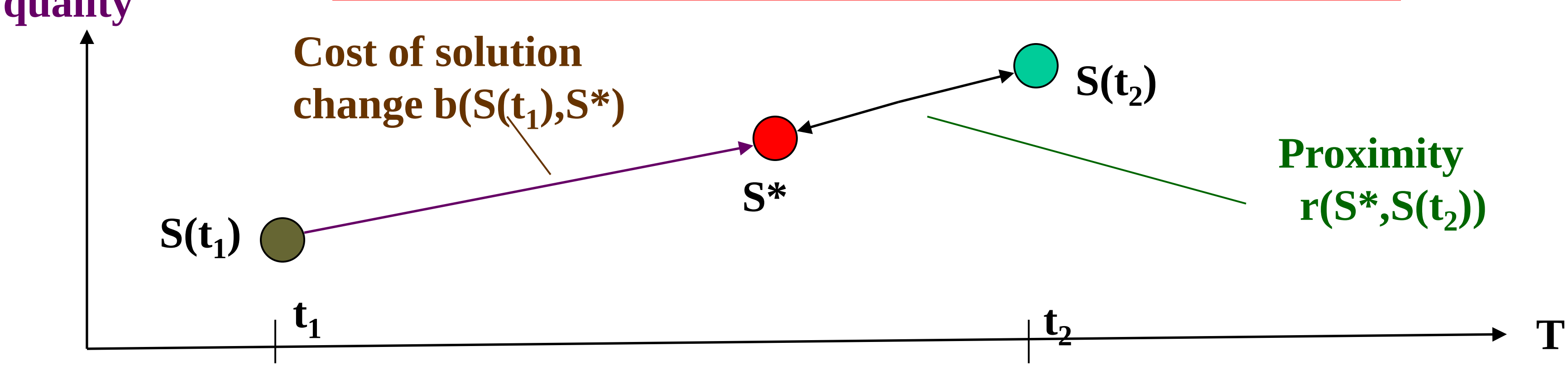
2.Restructuring (knapsack, multiple choice problem, spanning tree, Steiner tree) [Levin, 2011]:

(a) Given an optimal solution at time moment t_1: $S(t_1)$

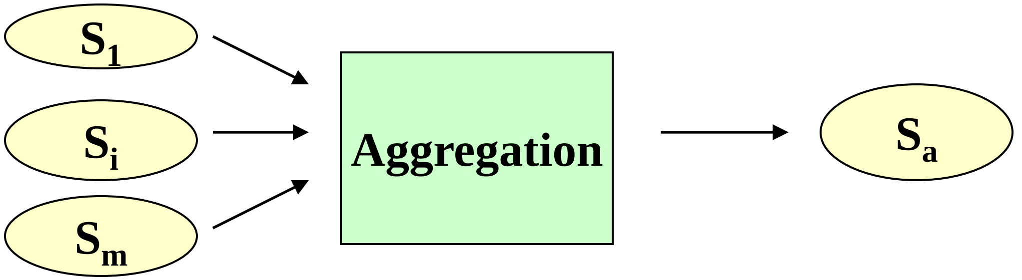
(b) Given an optimal solution at the next time moment t_2: $S(t_2)$

Problem: Find a change of solution $S(t_1)$ (by typical change operations) to obtain new solution S^* , that is 'close' (by solution structure) to solution $S(t_2)$

General problem: min $r(S^*,S(t_2))$, min $b(S(t_1),S^*)$



2.6.AUXILIARY SCHEME: aggregation of modular solutions

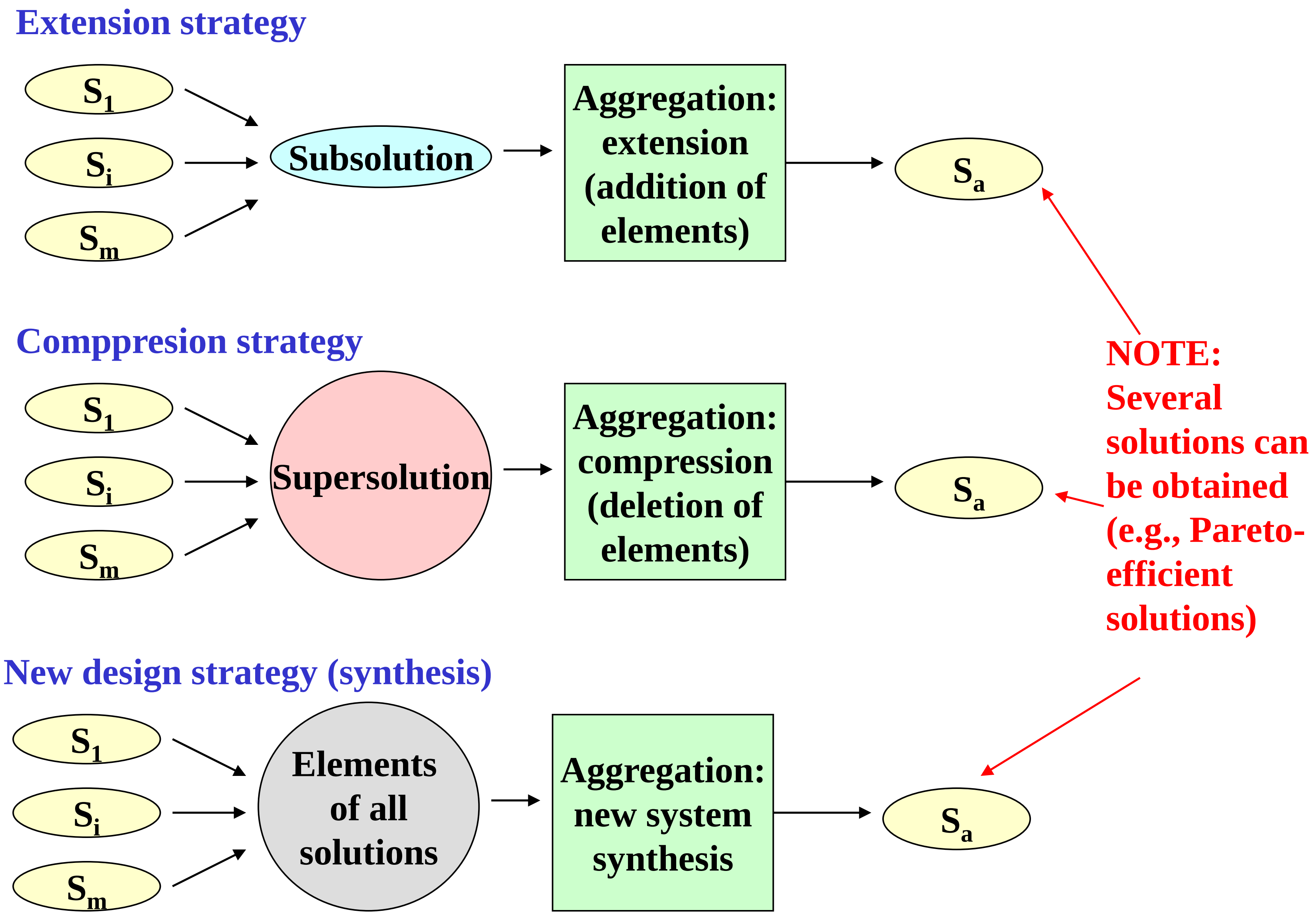


Types of solutions:
1.Set 2.Ranking 3.Tree 4.Morphological model

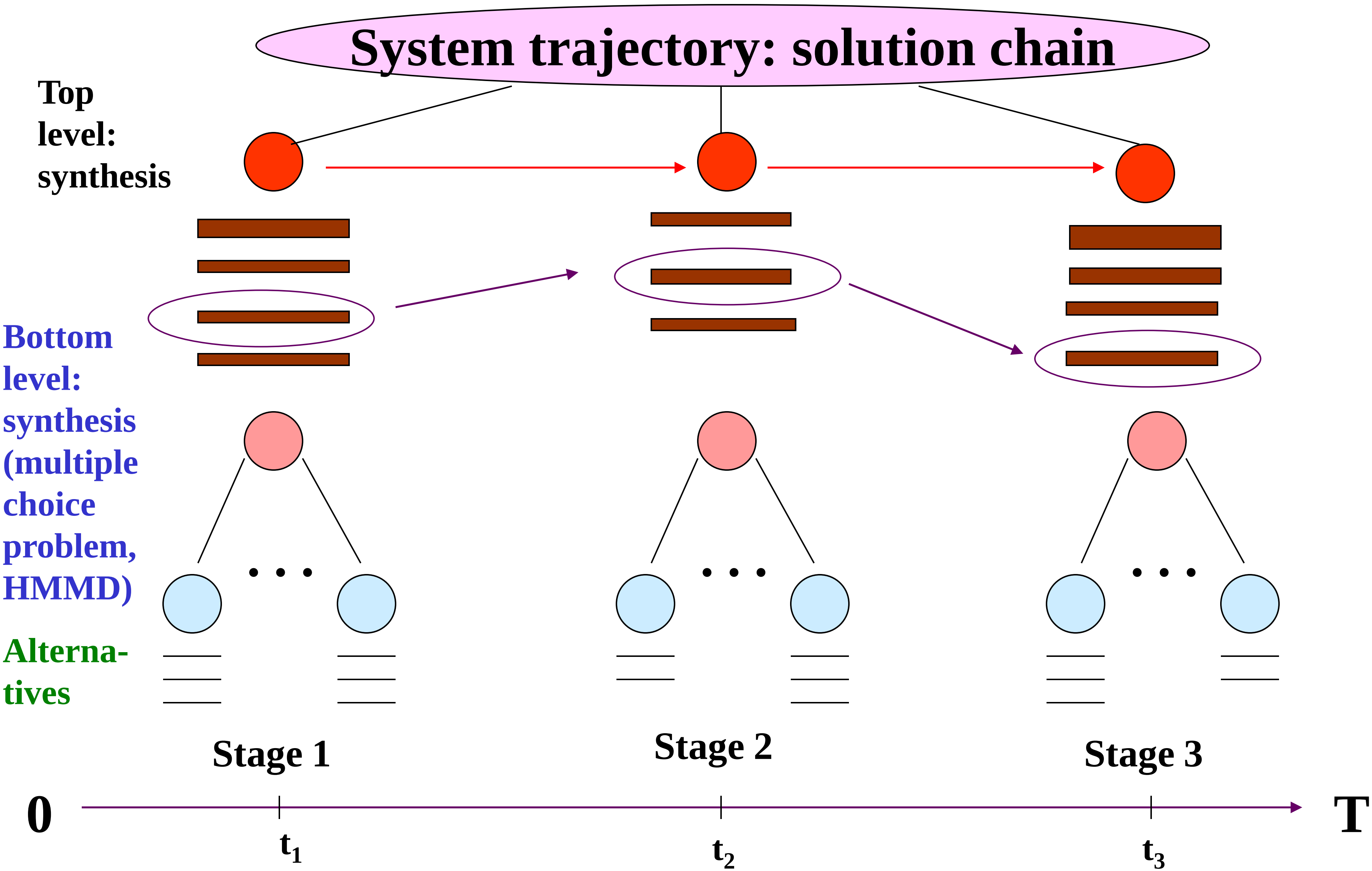
Strategies:
1.Detection of system kernel (subsolution - substructure) and extension of the kernel (multiple choice problem, HMMD)
2.Design of supersolution (superstructure) and deletion of some elements (multiple choice problem HMMD)
3.Extended system design (design with addition al design elements)

Support problems:
1.Proximity between modular solutions (sets, rankings, trees, morphological models)
2.Design: supersolution (superstructure) and subsolution (substructure)
3.Design: median, consensus (e.g., agreement tree)

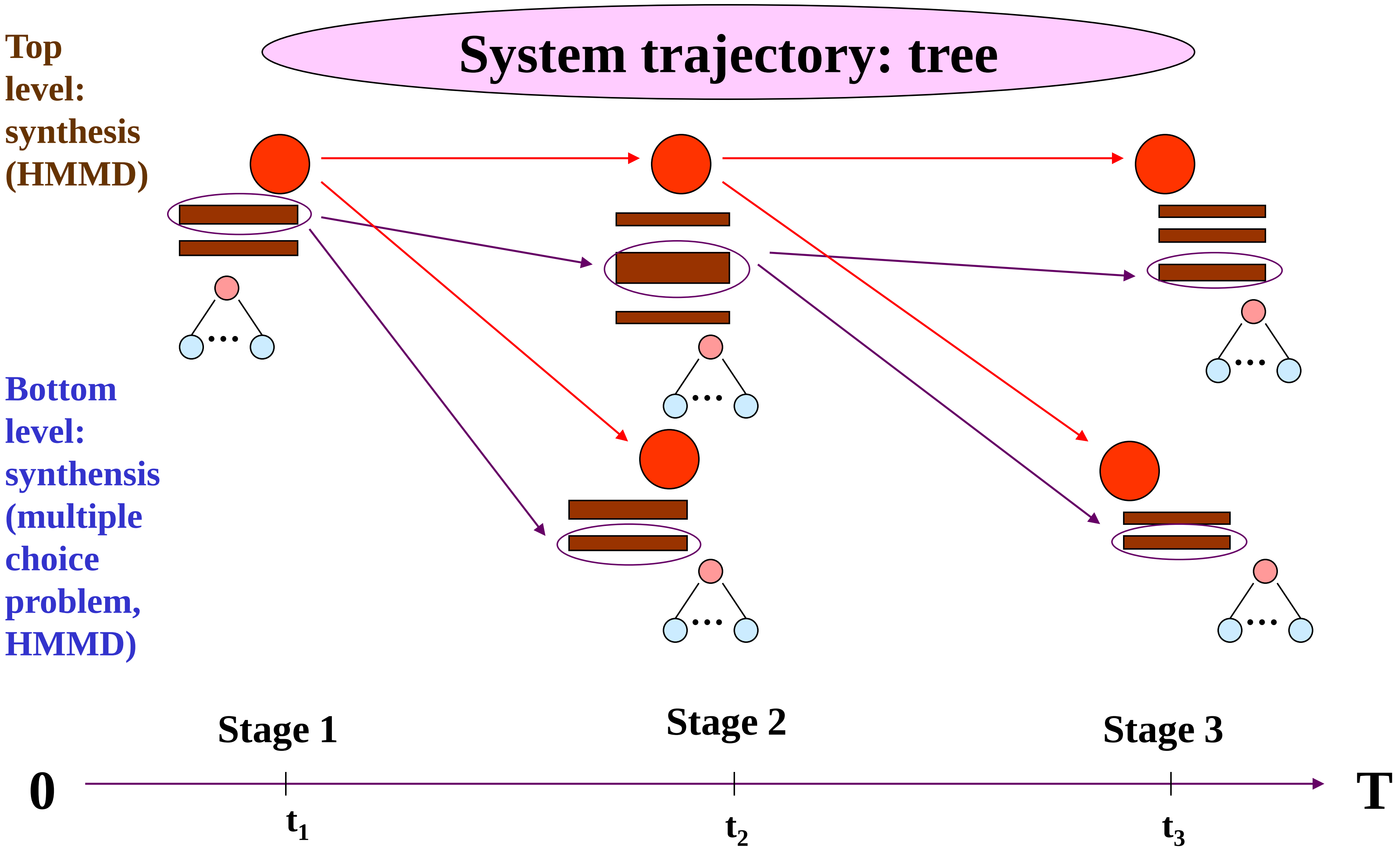
2.6.AUXILIARY SCHEME: aggregation of modular solutions



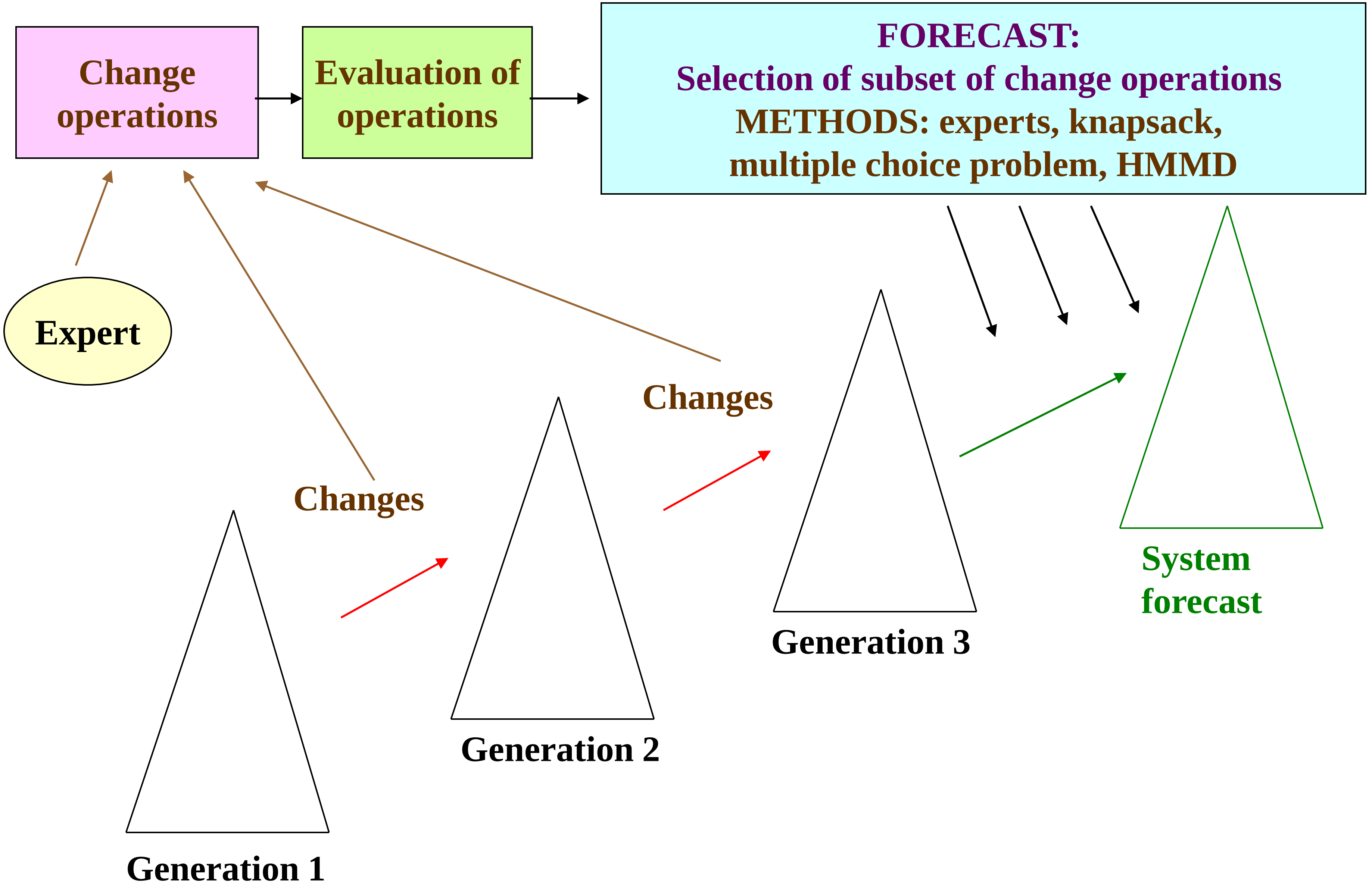
2.7.SCHEME 6: Multistage system design



2.7.SCHEME 6: Multistage system design



2.8.SCHEME 7: combinatorial system evolution and forecasting



Part 3. Some illustrative applied examples

PLAN:

3.0.Basic author's references

3.1.Design of four-member team: 3.1.1.Design example 3.1.2.Improvement example

3.2.Improvement of telephone network (in Moscow)

3.3.Example of network extension

3.4.Evolution: generations of DSS COMBI

3.5.Evolution: generations MPEG standard

3.6.Evolution: generations of image processing system

3.7.Evolution and forecasting of Zig Bee protocol (for sensor networks)

3.8.Evolution of wireless communication systems (1G,…6G), improvement of 5G

3.9.Example: Location of employees into rooms (usage of HMMD)

3.0.Basic author's references - A

I.Books:

3.1.Levin M.Sh. Modular System Design and Evaluation, Springer, 2015.

3.2.Levin M.Sh. Composite Systems Decisions. Springer, 2006.

3.3.Levin M.Sh. Combinatorial Engineering of Decomposable Systems, Springer, 1998.

II.Papers:

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3.2.Levin M.Sh. Towards combinatorial modeling of wireless technology generations. Electr. prepr., 20 p., Sep. 2, 2017; http://arxiv.org/abs/1708.08996[cs.NI]

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II.Papers:

3.9.Levin M.Sh. Modular system synthesis: example for composite packaged software. IEEE Trans. on SMC, part C, 35(4), 544-553, 2005.

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3.13.Levin M.Sh. Digraph based medical treatment planning. 2015 Int. Conf. onBiomedical Engineering and Computational Technologies (SIBIRCON), IEEE Press, 171-175, 2015.

3.14.Levin M.Sh. Towards electronic shopping of composite product. Electr. Prepr., 10 p., Mar. 3, 2012; http://arxiv.org/abs/1203.0648[cs.SE]

3.15.Levin M.Sh. Towards configuration of applied web-based information system. Electr. Prepr., Aug. 31, 2011; http://arxiv.org/abs/1108.6223[cs.SE]

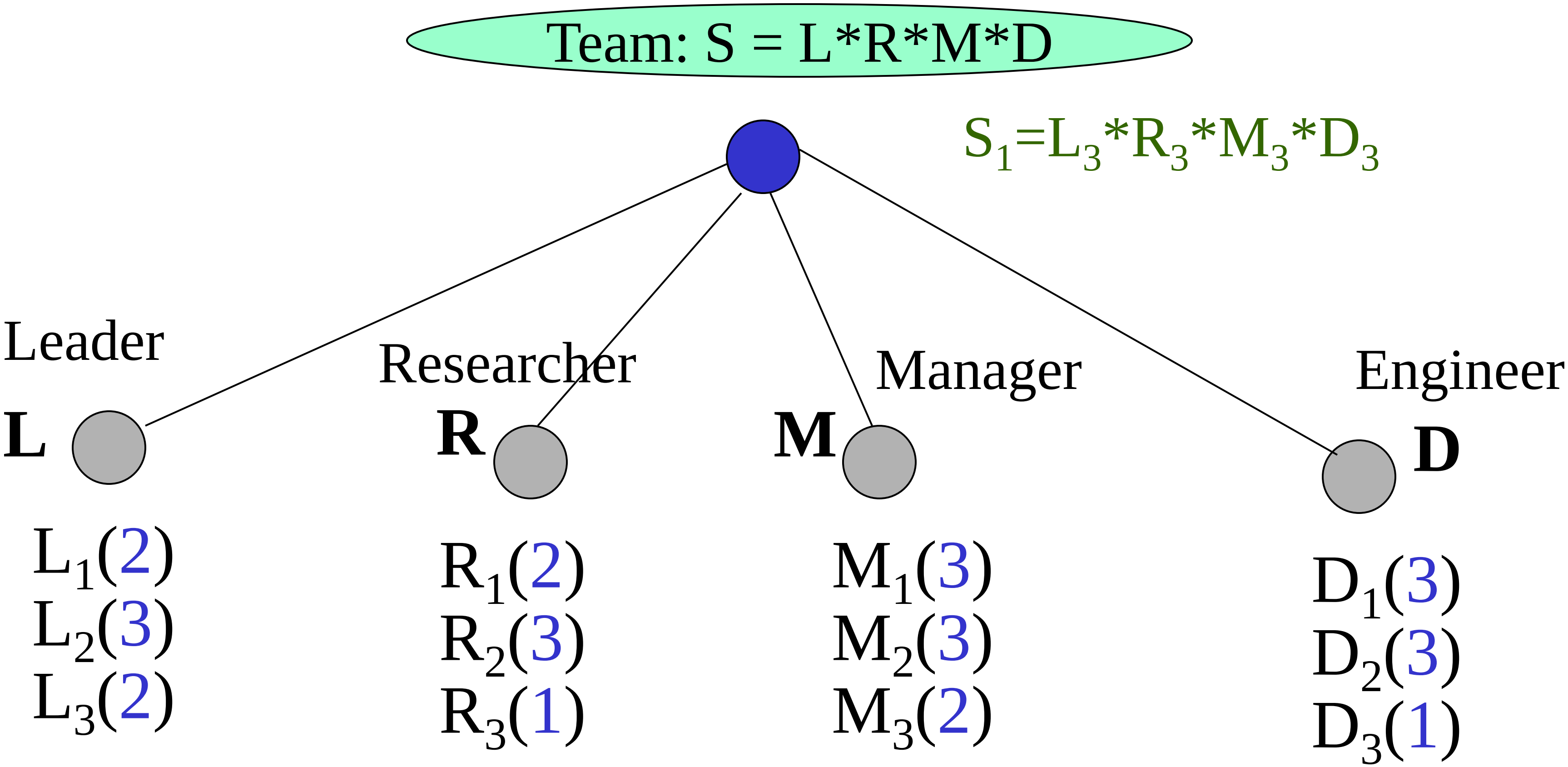
3.16.Levin M.Sh. Course on system design (structural approach). Electr. Prepr., 22 p., Mar. 20, 2011; http://arxiv.org/abs/1103.3845[cs.SE]

3.17.Levin M.Sh. Towards communication network development (structural system issues, combinatorial models). IEEE Region 8 Int. Conf. Sibircon-2010, vol. 1, 204-208, 2010.

3.18.Levin M.Sh. Student research projects in system design. Int. Conf. on Computer Supported Education CSEDU 2009, Lisbon, vol. 2, 67-72, 2009.

3.19.Levin M.Sh. Morphological approach to electronic shopping. IEEE Region 8 Int. Conf. Sibircon-2008, 280-285, 2008.

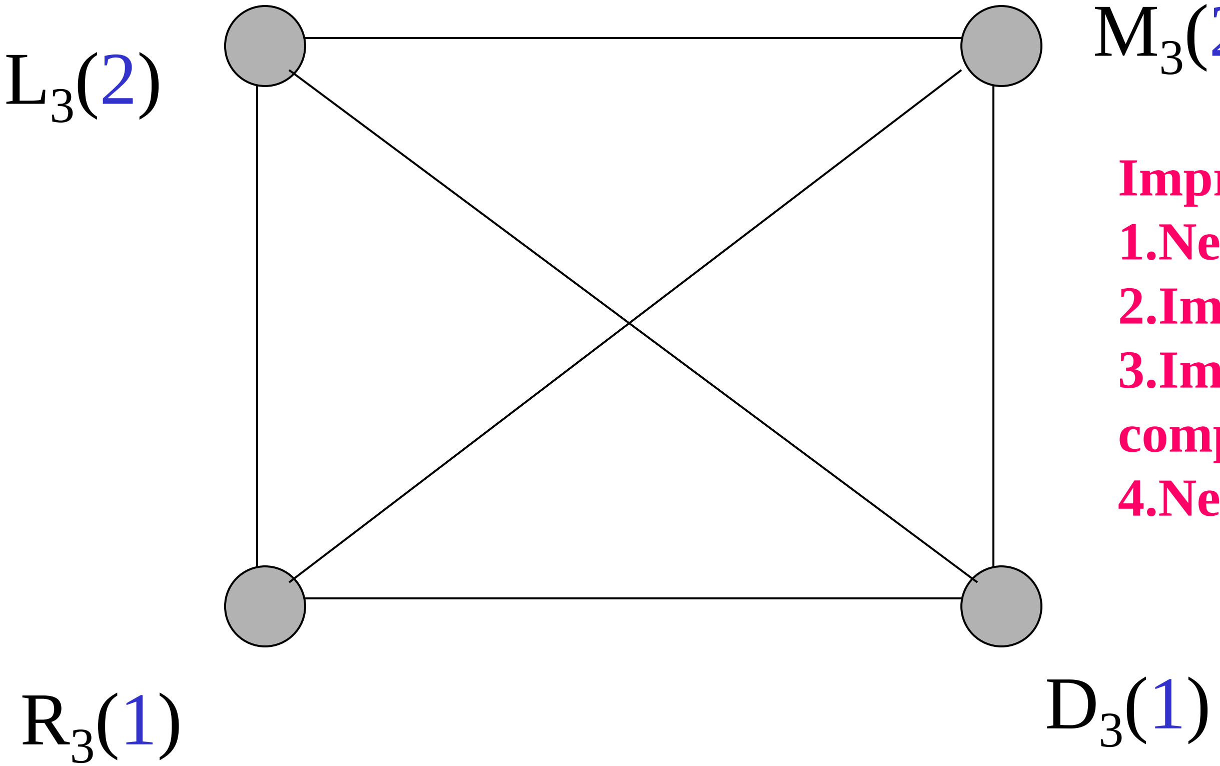
3.1.Example: Design of four team



3.1.Example: Design of four member team

Team: S = L*R*M*D

$S_1 = L_3 * R_3 * M_3 * D_3$



Improvement actions:

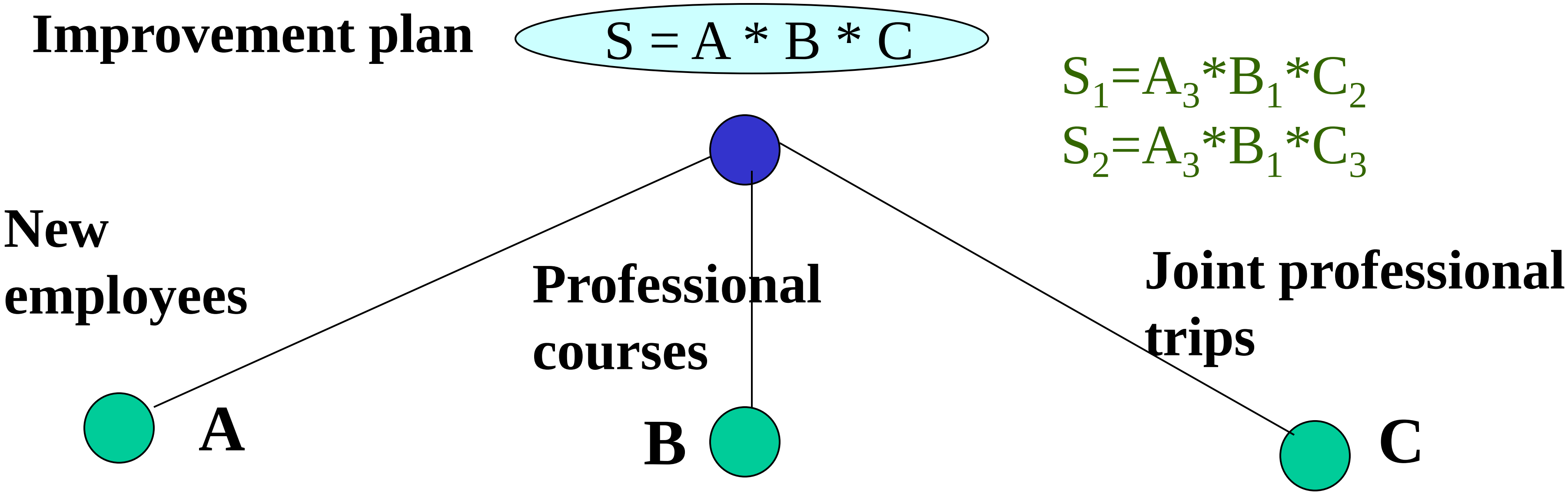
1.New employee

2.Improvement of employee

3.Improvement of employee compatibility

4.New team structure

3.1.Example: Improvement of team



$S_1=A_3*B_1*C_2$

$S_2=A_3*B_1*C_3$

$A_1(2)$
$A_2(2)$
$A_3=A_1\&A_2(2)$

$B_1(1)$
$B_2(2)$
$B_3(1)$
$B_4(1)$
$B_5=B_3\&B_4(2)$
$B_6=B_1\&B_4(3)$
$B_7=B_1\&B_2\&B_4(3)$

$C_1(2)$
$C_2(1)$
$C_3(1)$
$C_4=C_1\&C_3(3)$

3.1.Design alternatives for team improvement

A_1 new leader

A_2 new manager

$A_3 = A_1$ & A_2

B_1 course on advancement in science & engineering

B_2 course on foreign language

B_3 course on system analysis

B_4 course on creativity methods

$B_5 = B_3$ & B_4

$B_6 = B_1$ & B_4

$B_7 = B_1$ & B_2 & B_4

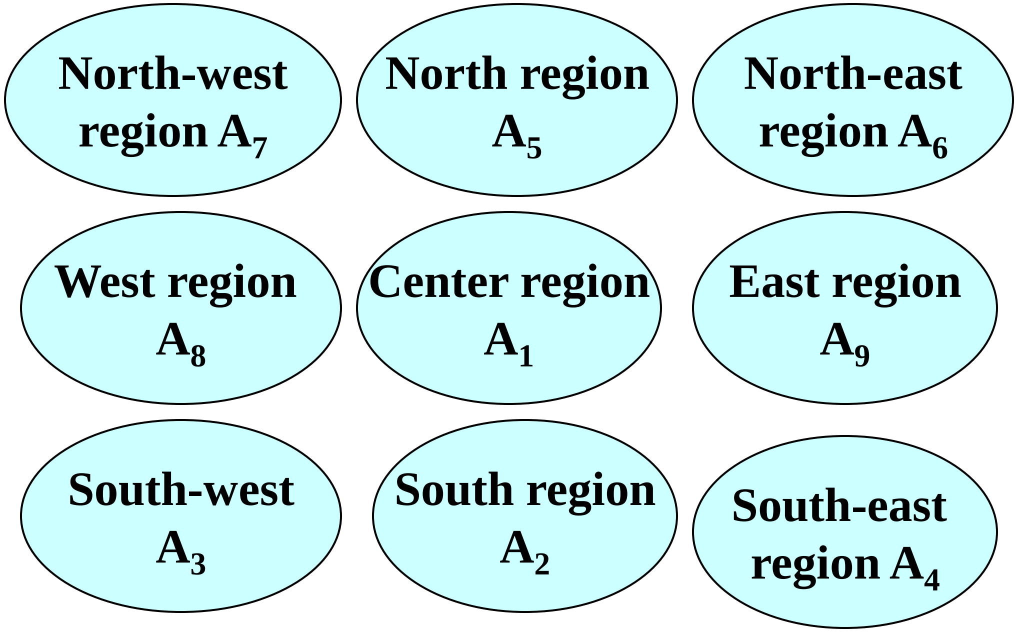
C_1 course on human relations

C_2 joint vacation trip

C_3 joint participation in research conference

$C_4 = C_1$ & C_2

3.2.Illustrative example: Improvement of telephone network in Moscow



Criteria:

C_1 total (generalized) utility

C_2 complexity of implementation

C_3 prospective utilit,

C_4 expenditure for implementation (apparatus, work)

GROUPS (clustering of the regions By parameters):

Group 1 (G^1): A_1

Group 2 (G^2): A_2

Group 3 (G^3): A_3&A_8

Group 4 (G^4): A_4

Group 5 (G^5): A_5&A_7&A_9

Group 6 (G^6): A_6

System extension activities/operation:

D_1 None

D_2 New links

D_3 Upgrade of links

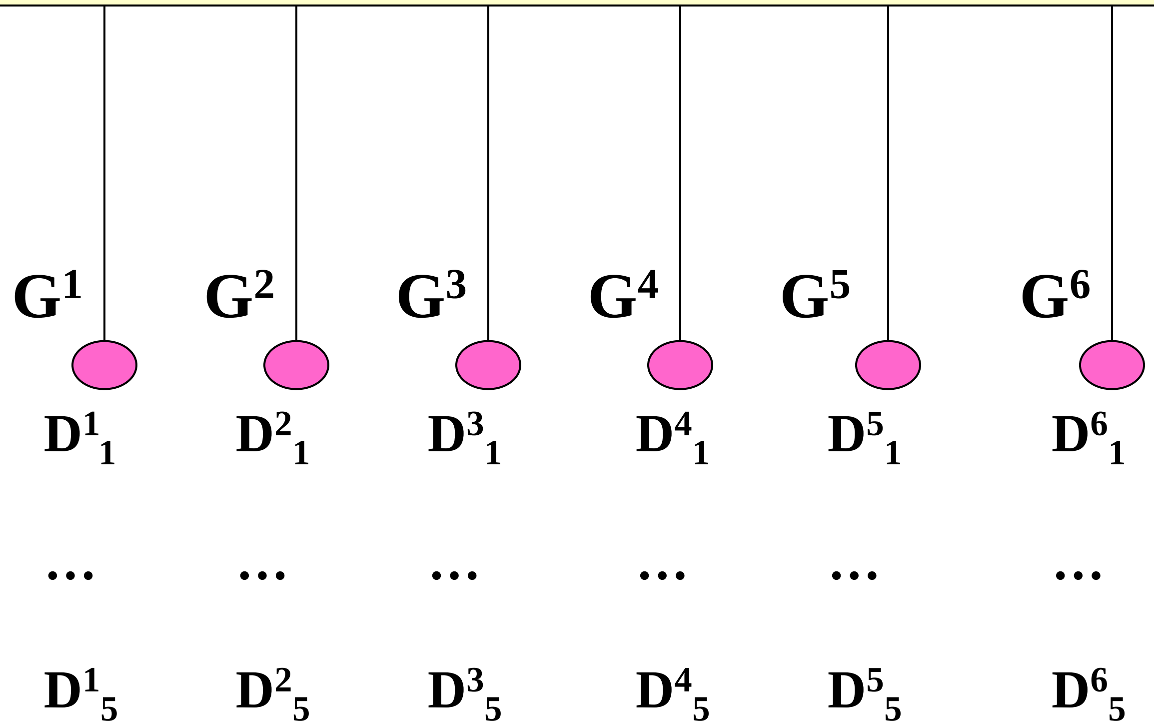
D_4 New links and new apparatus

D_5 Deletion of some old links

3.2.Illustrative example: Improvement of telephone network in Moscow

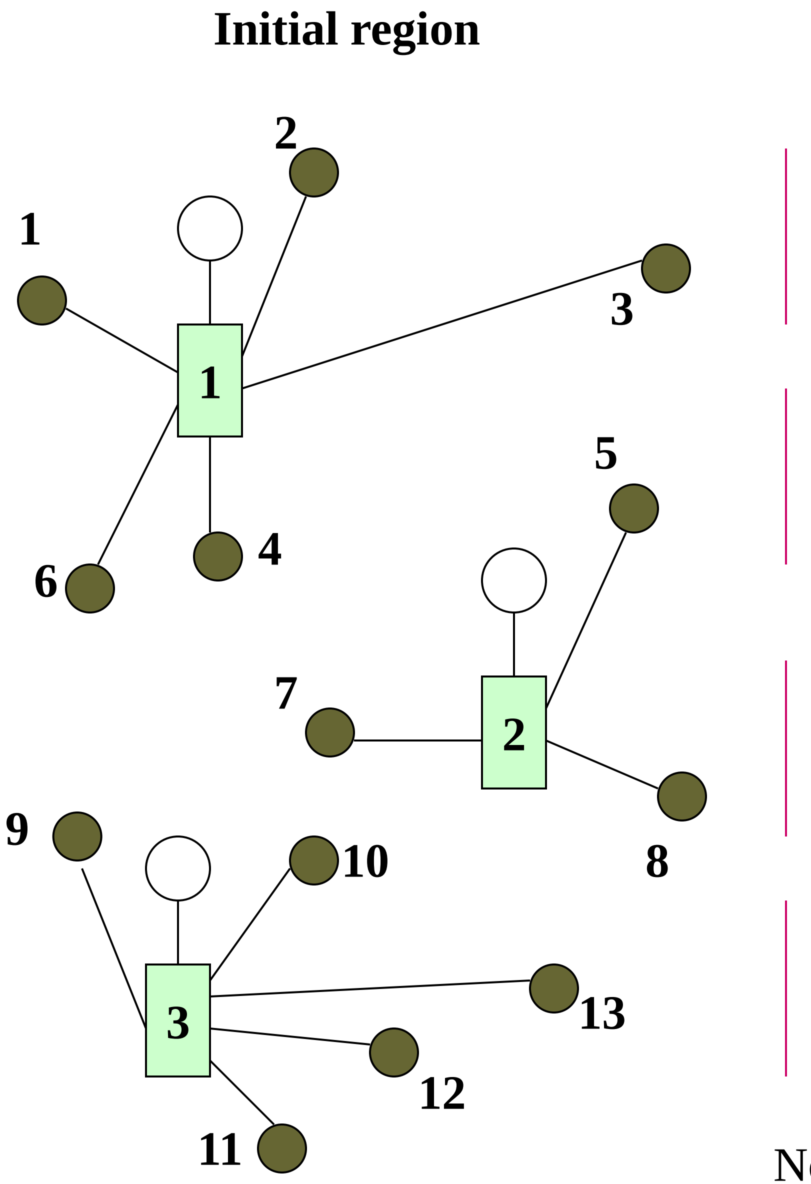
System $S = G^1 * \ldots * G^i * \ldots * G^6$

Example of improvement activity: $P_1 = D^1_3 * \ldots * D^3_2 * \ldots * D^6_1$



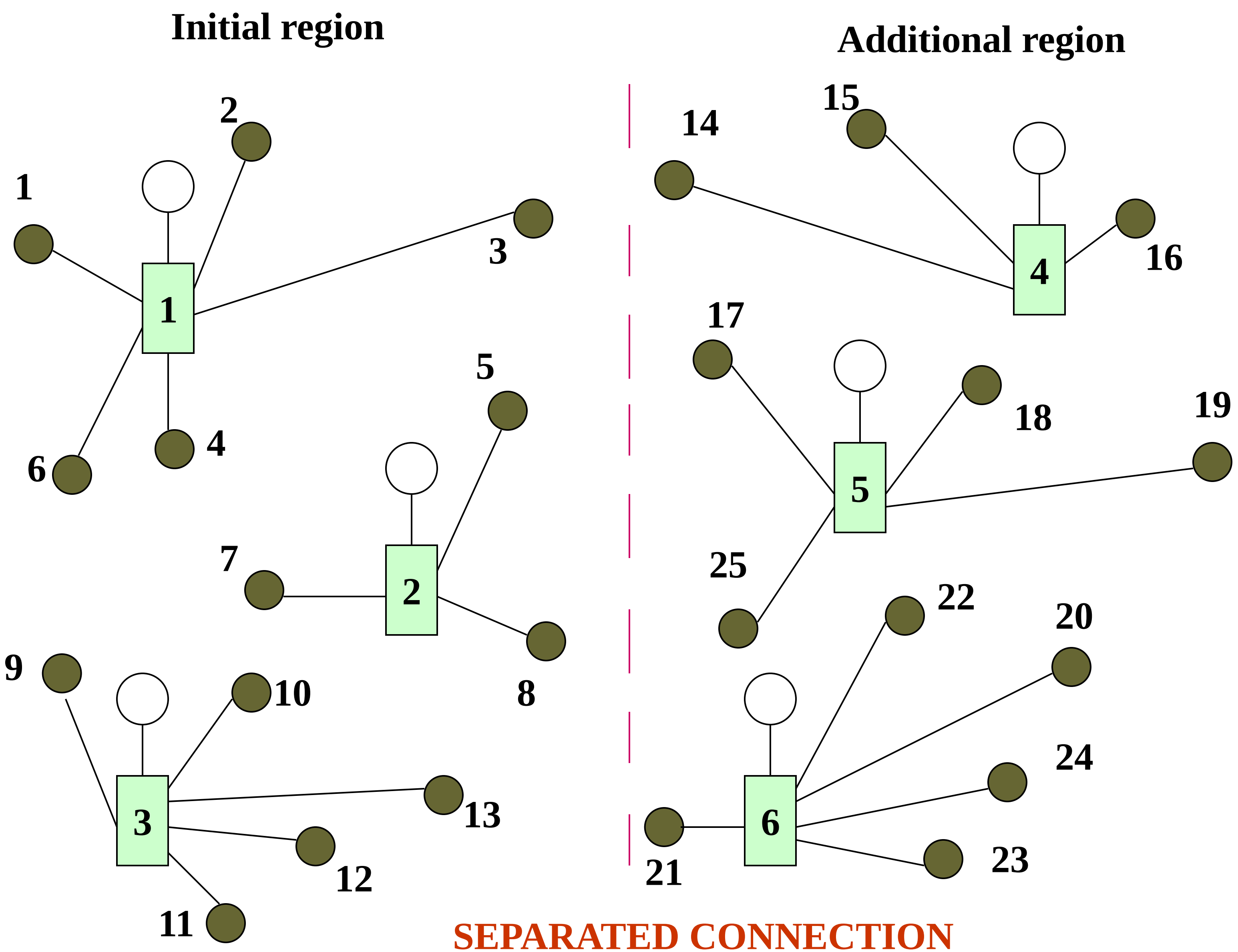
Note: multiple choice problem

3.3.Example of network extension



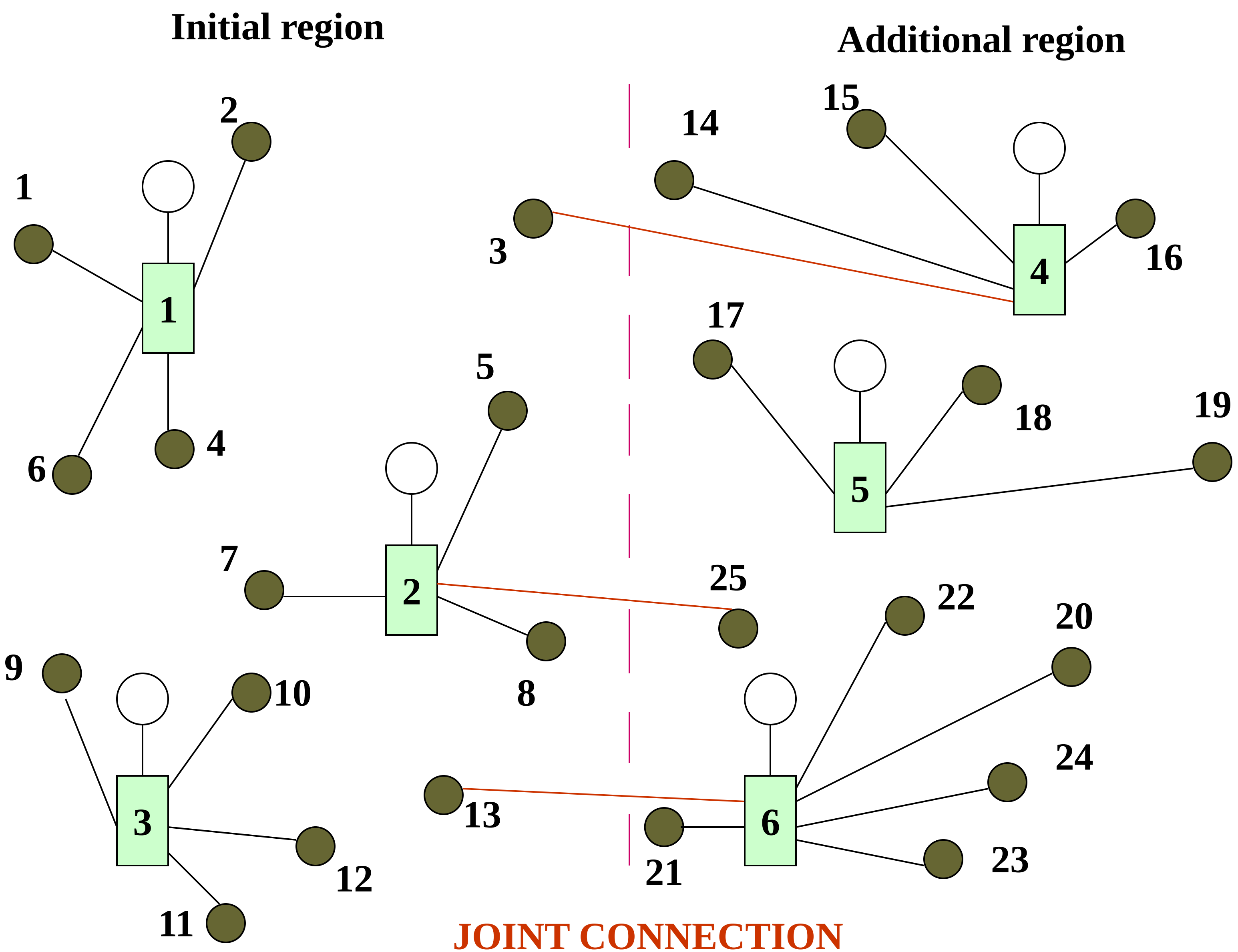
Note: generalized multicriteria assignment problem

3.3.Example of network extension

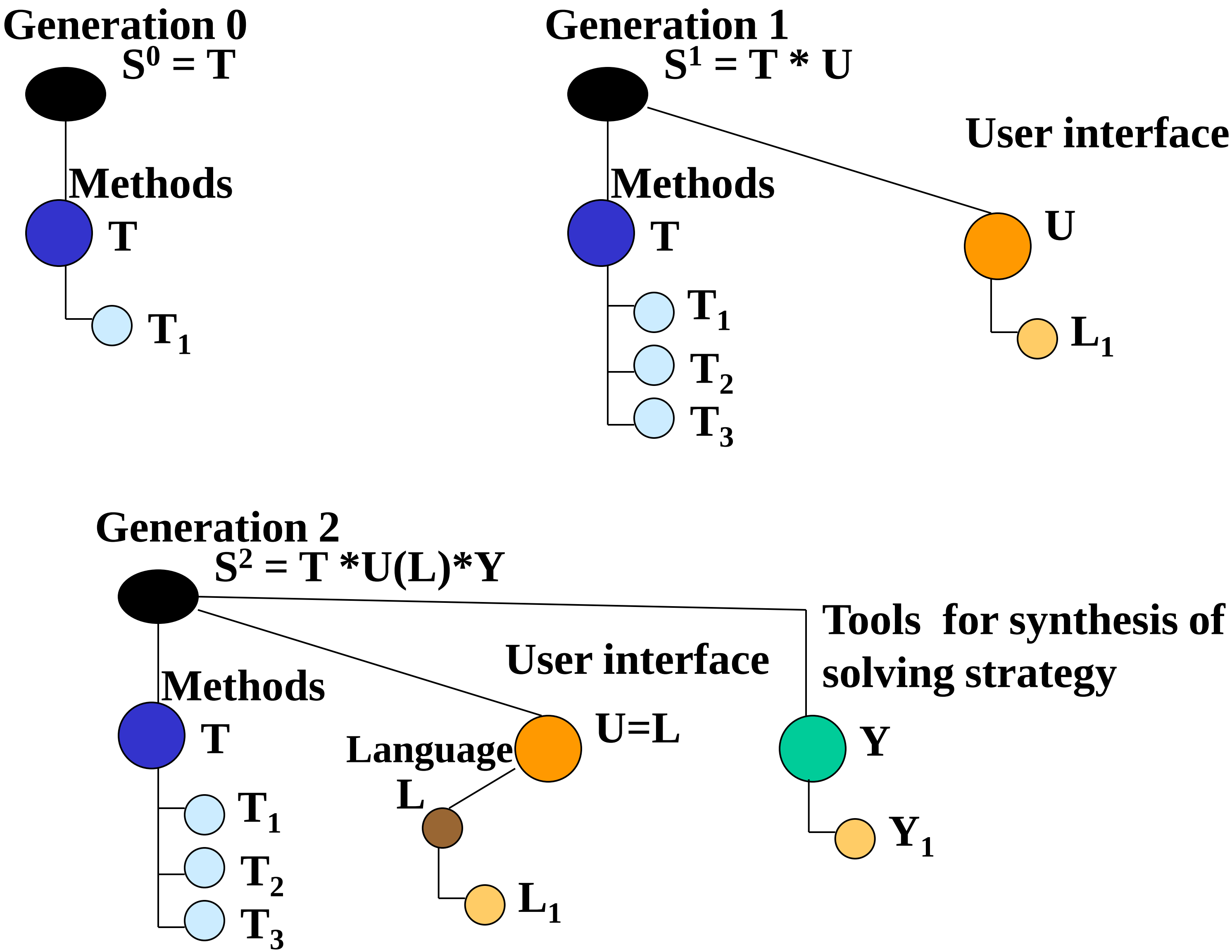


SEPARATED CONNECTION

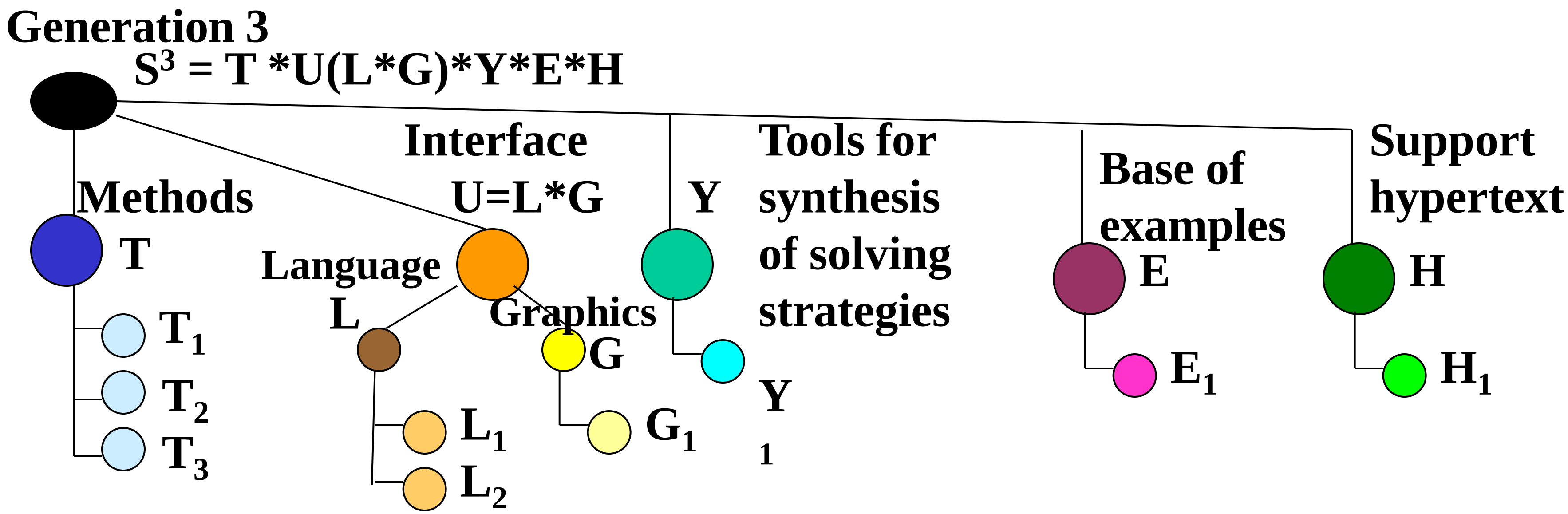
3.3.Example of network extension

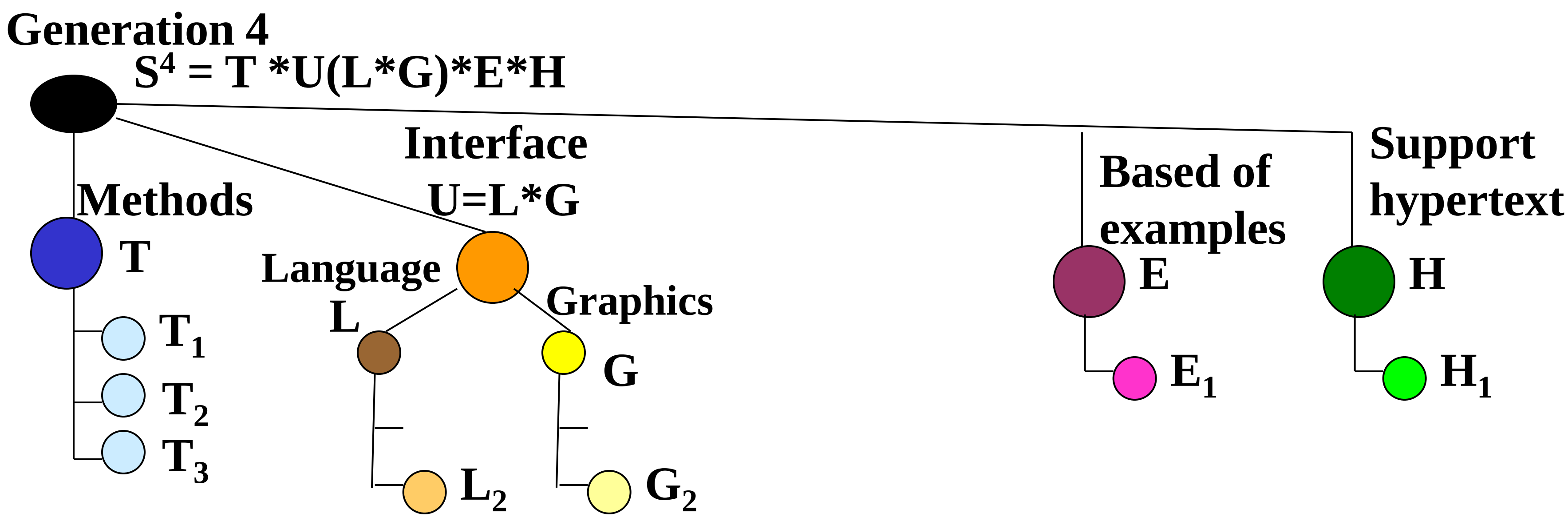


3.4.Example: generations of DSS COMBI (ranking; 1984…1993) [Levin, 1994]

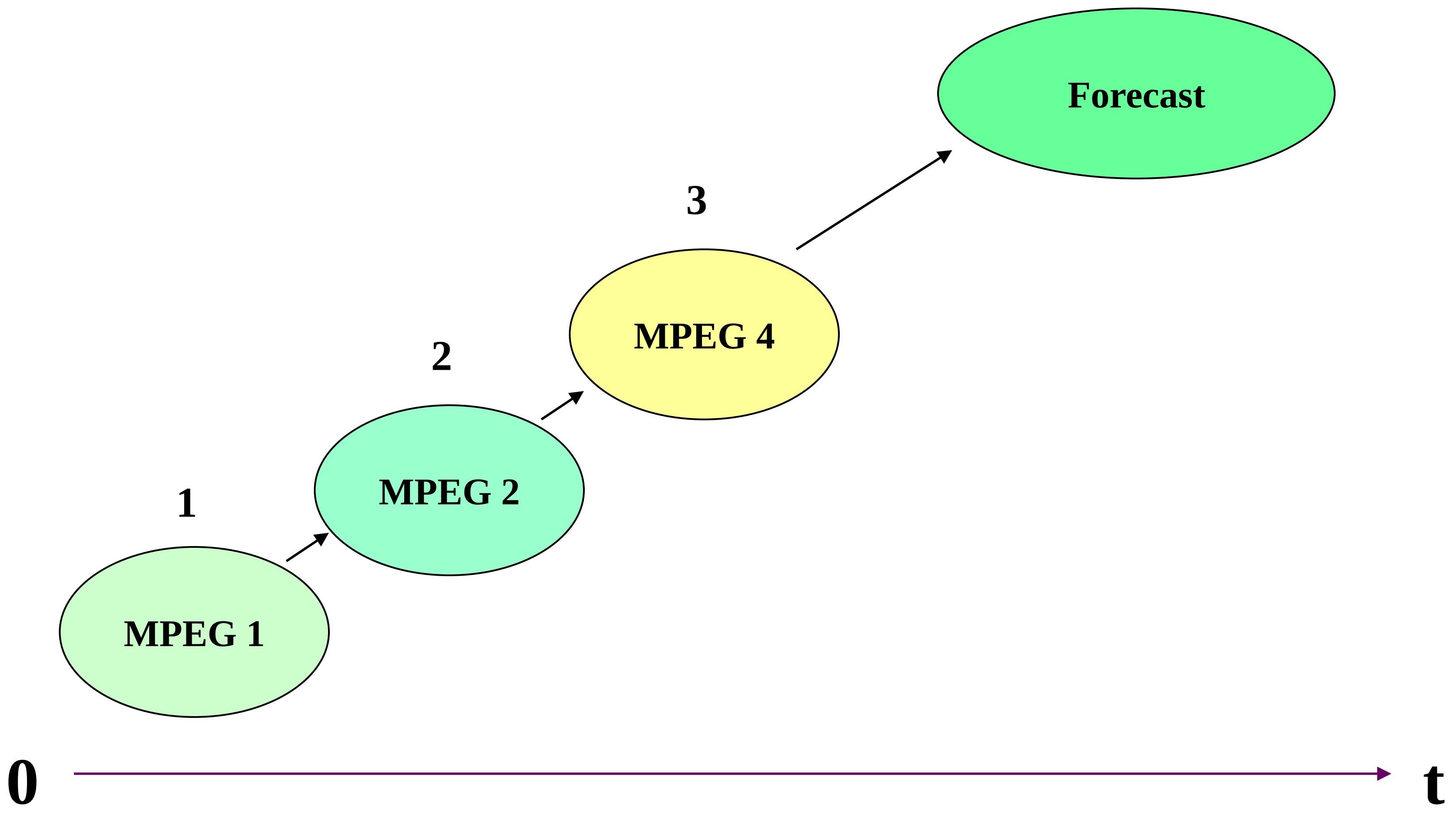


3.4.Example: generations of DSS COMBI (ranking; 1984…1993) [Levin, 1994]

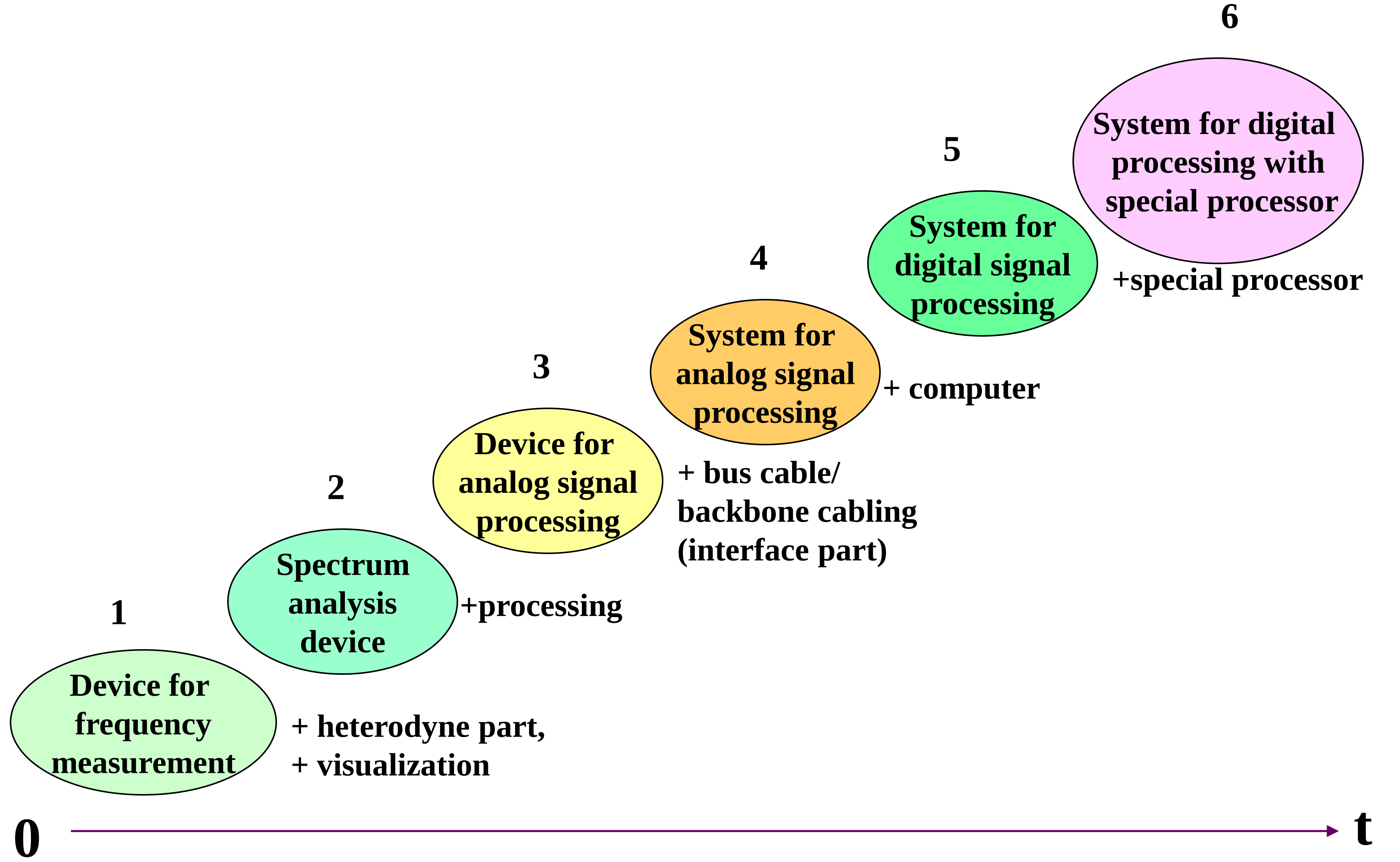




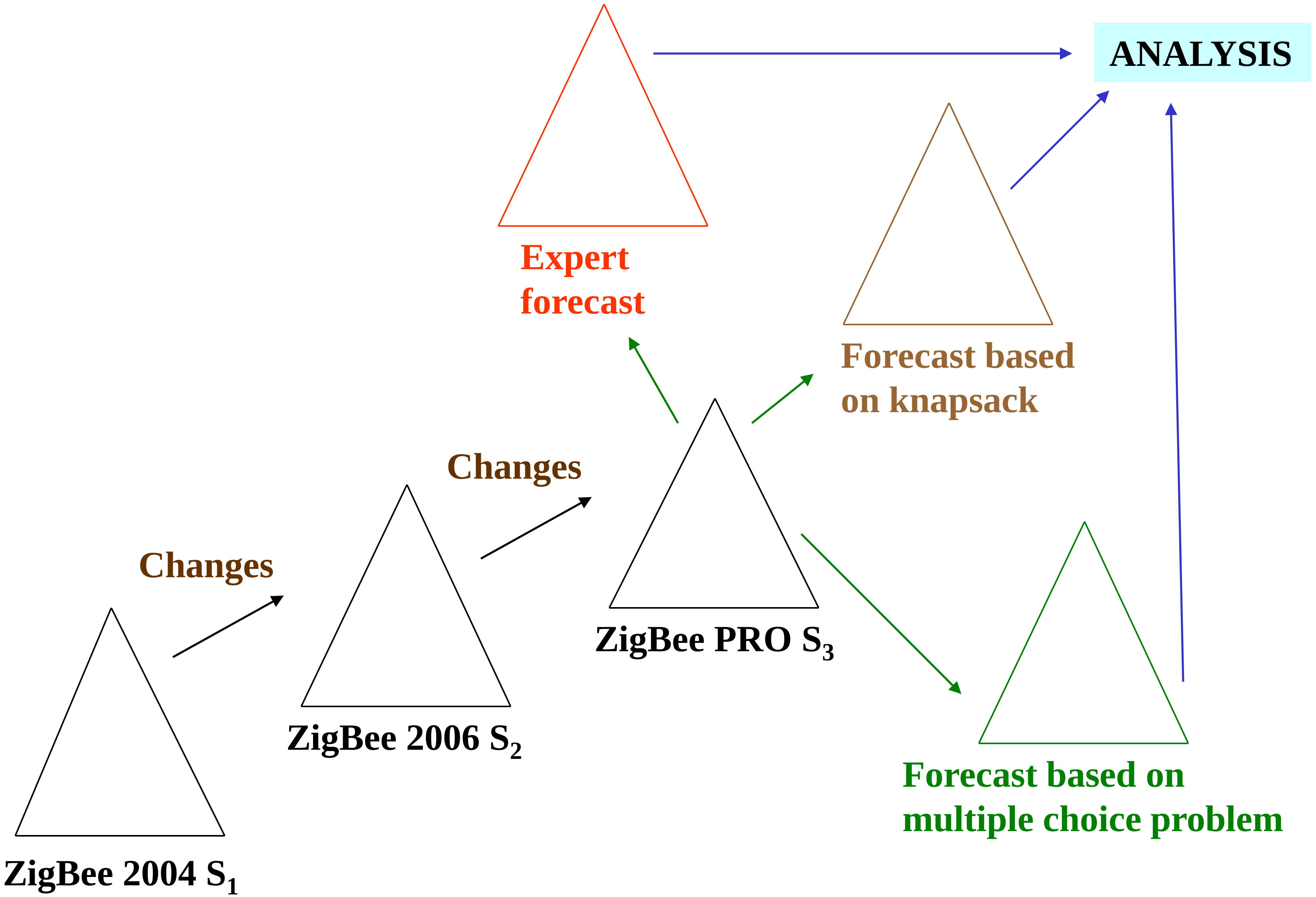
3.5.Example: Standard of multimedia data transmission MPEG



3.6.Example: Combinatorial evolution of image processing system (Levin,2006)



3.7.Example: evolution of ZigBee protocol (for sensor networks) [Levin et al., 2009..2013]

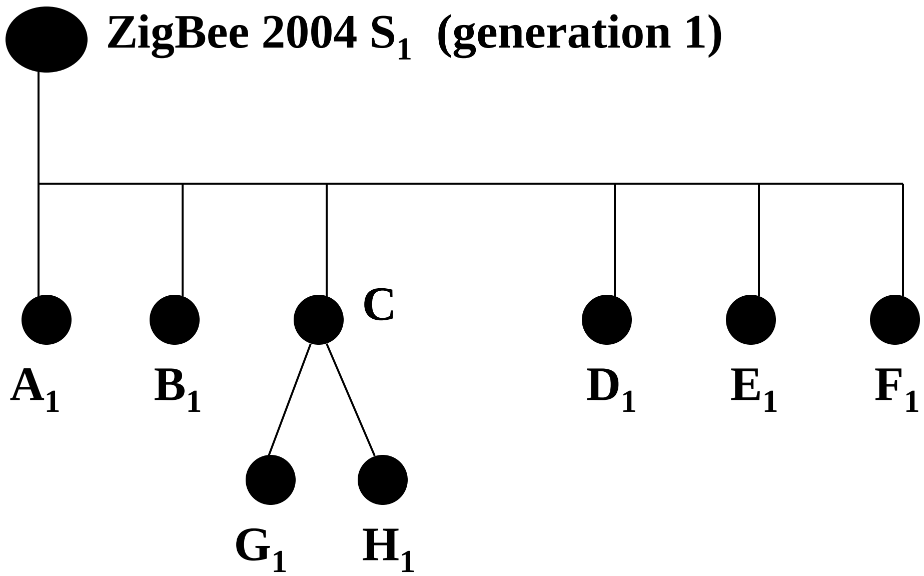


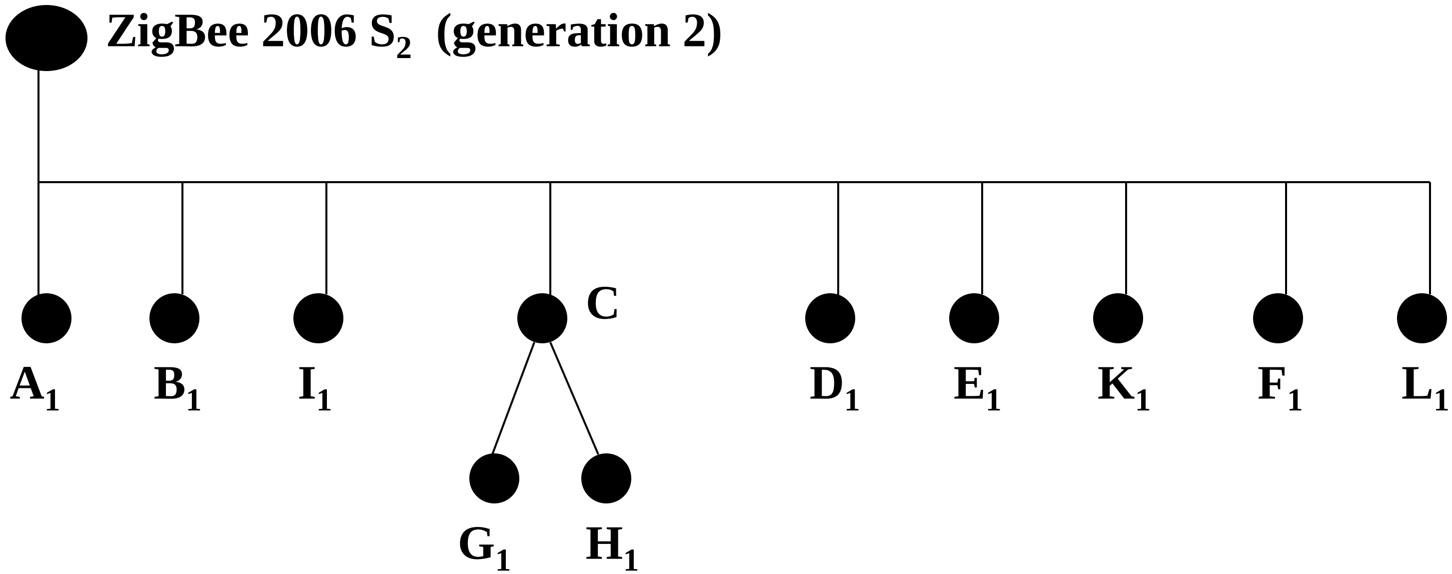
3.7.Example: General structure of ZigBee protocol

System parts:

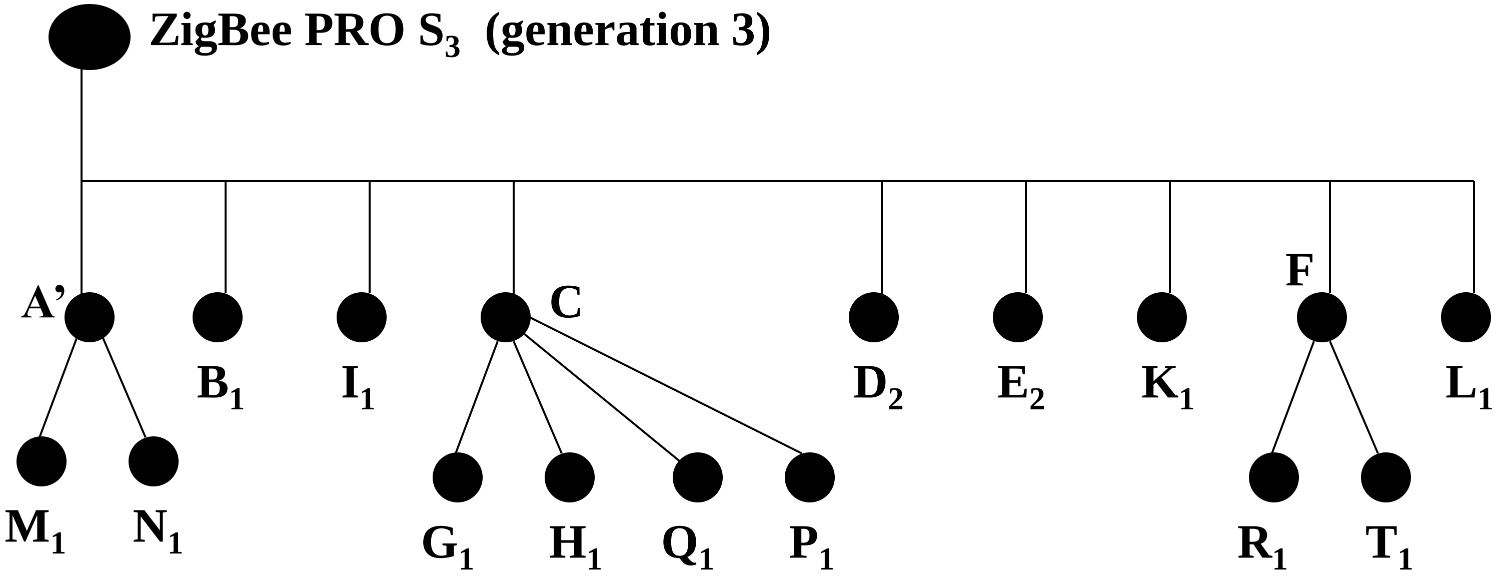
1.Interference avoidance A
2.Automated/distributed address management B
3.Group addressing I
4.Centralized data collection C
5.Network scalability D
6.Message size E
7.Standardized commissioning K
8.Robust mesh networking F
9.Cluster library support L
10.Web services support W

3.7.Example: generations of ZigBee protocol

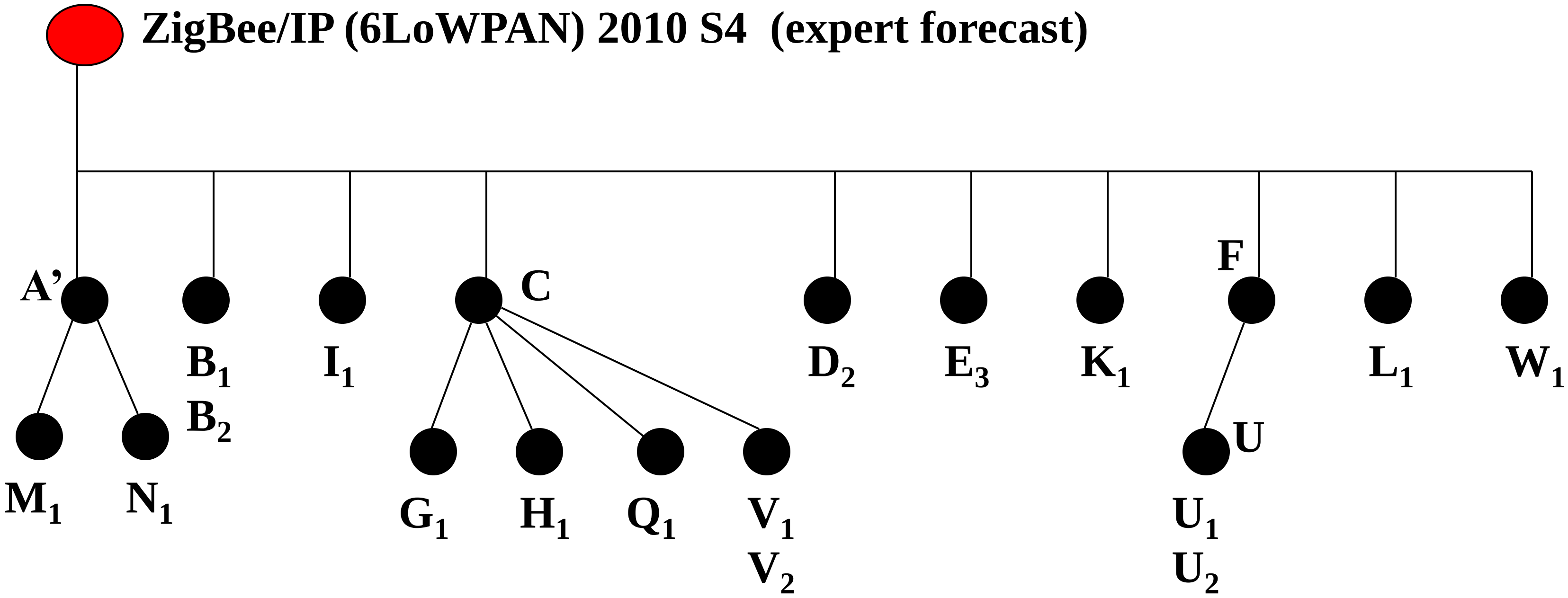




3.7.Example: generations of ZigBee protocol



3.7.Example: Direct expert forecast for ZigBee protocol



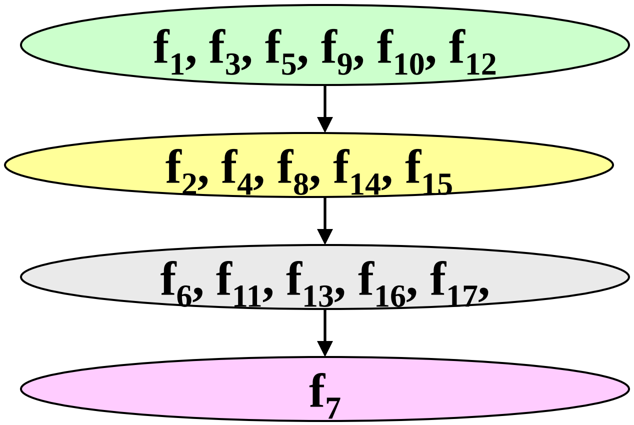
3.7.Example: Change operations and their estimates

Stage 1. Change operations:

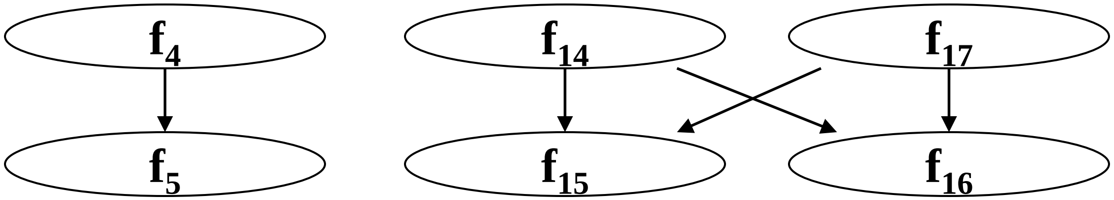
$f_1, f_2, f_3, f_4, f_5, f_6, f_7, f_8, f_9, f_{10}, f_{11}, f_{12}, f_{13}, f_{14}, f_{15}, f_{16}, f_{17}$

Stage 2. Assessment upon 8 criteria
(required time, effectiveness, scalability, reliability, utility, etc.)

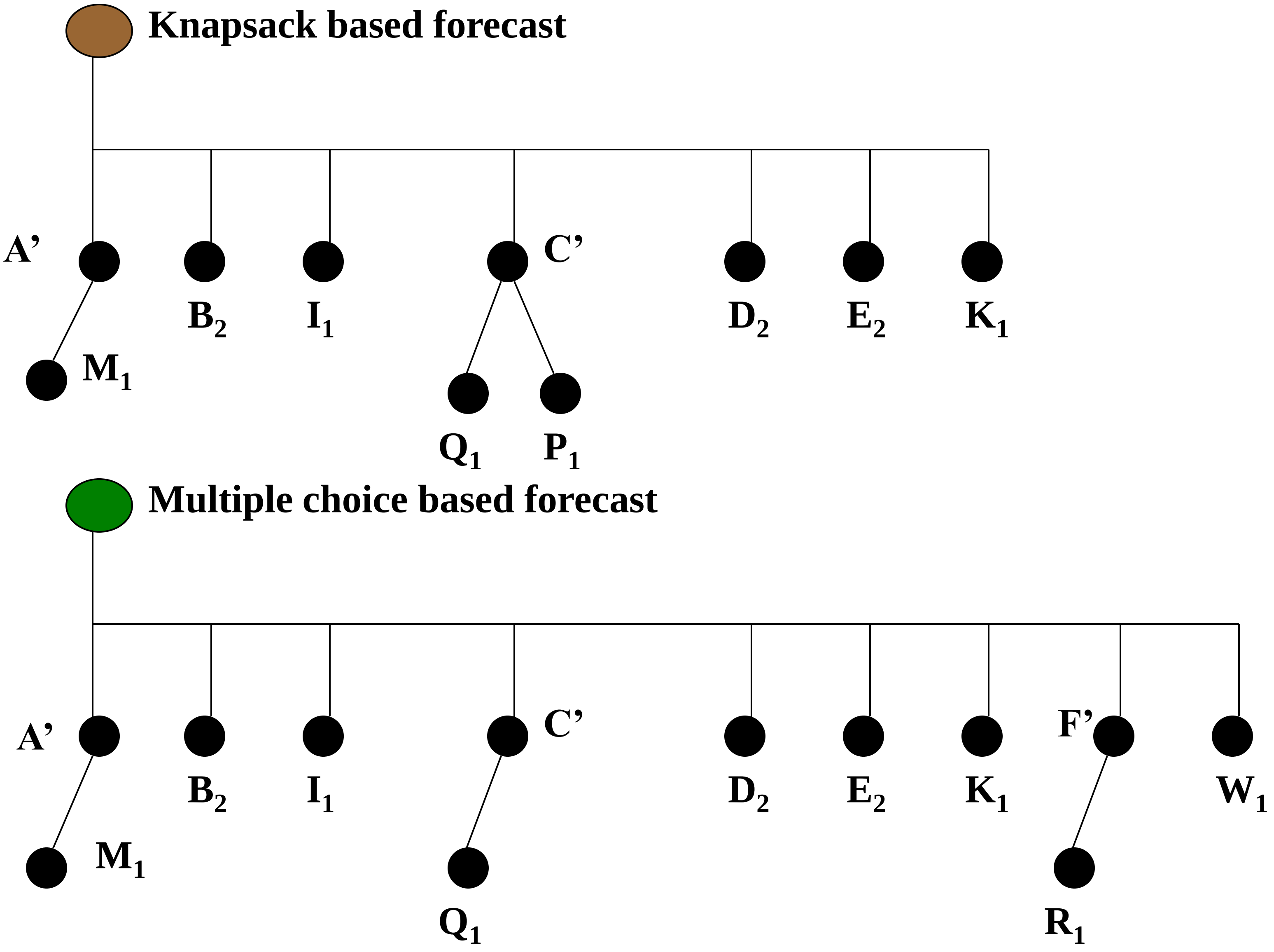
Stage 3. Multicriteria ranking



Stage 4. Design of binary relations over change operations
(equivalence, complementarity, precedence)

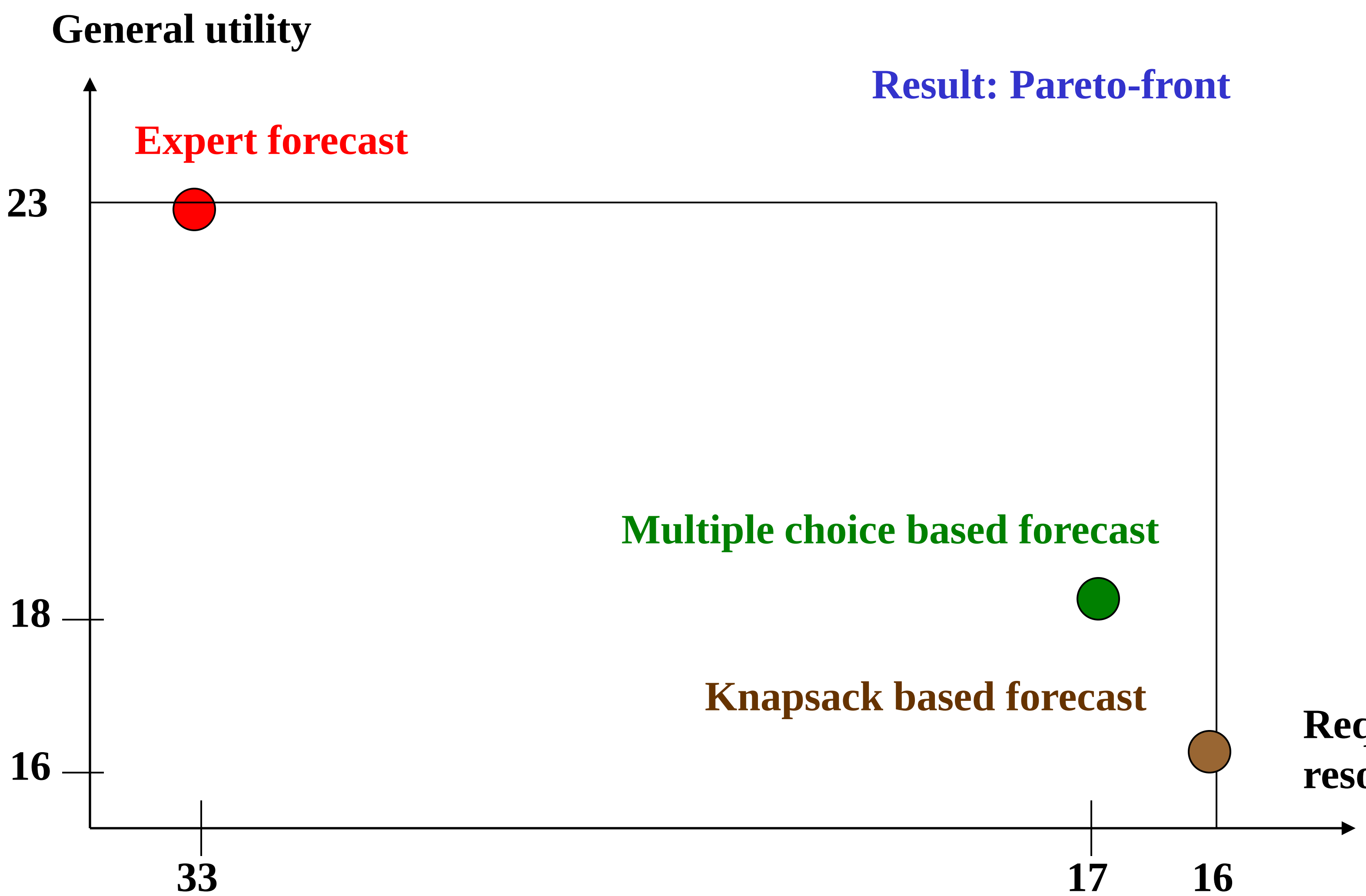


3.7.Example: Calculated forecast solutions

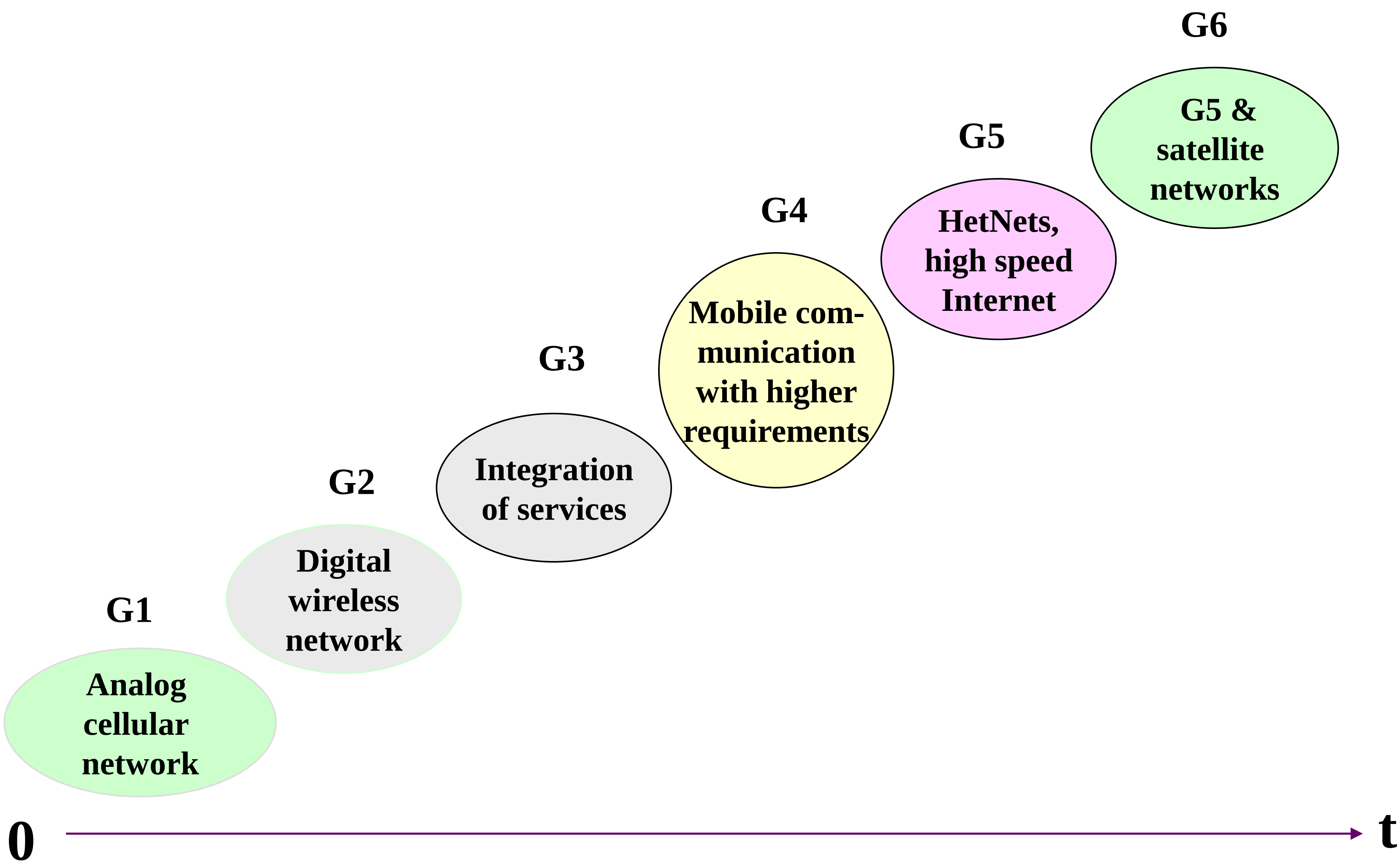


3.7.Comparison of calculated forecast solutions

Methods for comparison/analysis: 1. expert judgment 2.Pareto-approach



3.8.Example: Combinatorial evolution of wireless communication (Levin,2017)



3.8.Example: Combinatorial evolution of wireless communication (Levin,2017)

Hierarchical structure of wireless mobile system generations:

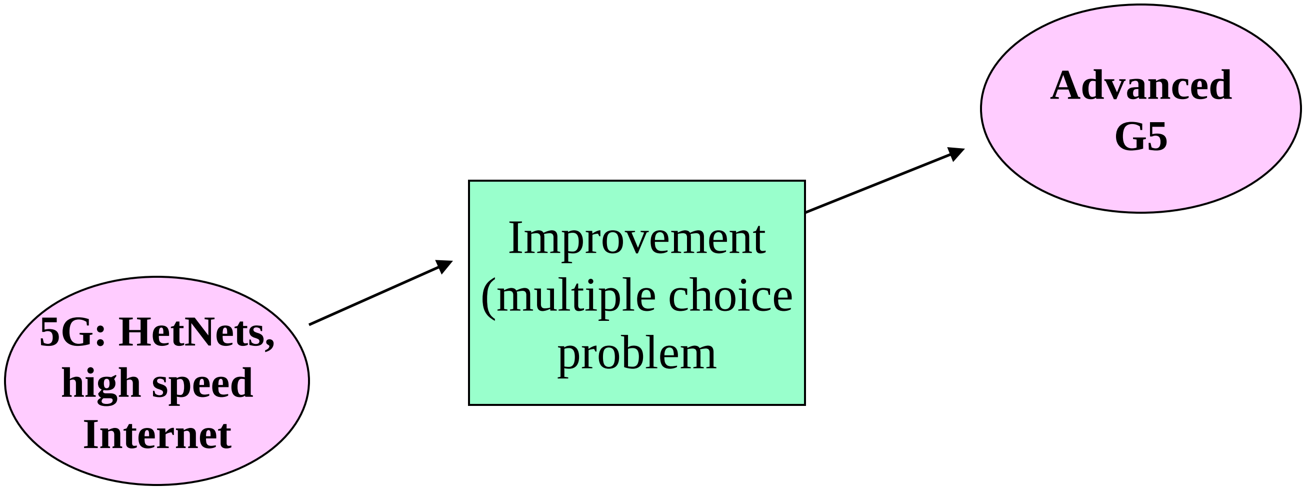
0. Wireless mobile system $S = B^1 * B^2 * B^3 * B^4$
1.Definition $B^1 = B^{11} * B^{12}$
1.1.technology (packet data, IP technology) B^{11}
1.2.switching (circuit, packet) B^{12}

2.Services $B^2 = B^{21} * B^{22}$
2.1.Service (mobile, digital voice, etc) B^{21}
2.2.cloud computing B^{22}
3.Data transmission & access $B^3 = B^{31} * B^{32}$
3.1.data bandwidth/throughput speed/data rate B^{31}
3.2.multiplexing/access technology B^{32}

4.Netrworking $B^4 = B^{41} * B^{42} * B^{43} * B^{44}$
4.1.core network B^{41}
4.2.handoff B^{42}
4.3.HetNets B^{43}
4.4.space communication B^{44}

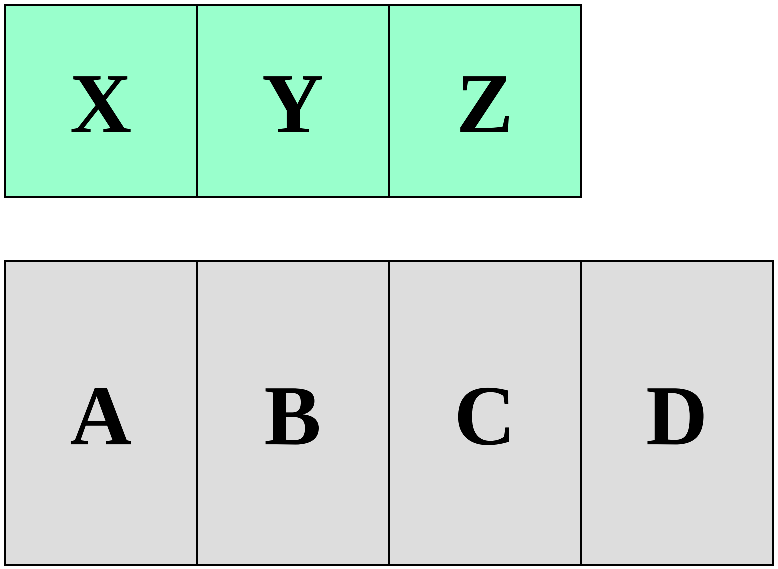
3.8.Example: Combinatorial evolution of wireless communication (Levin,2017)

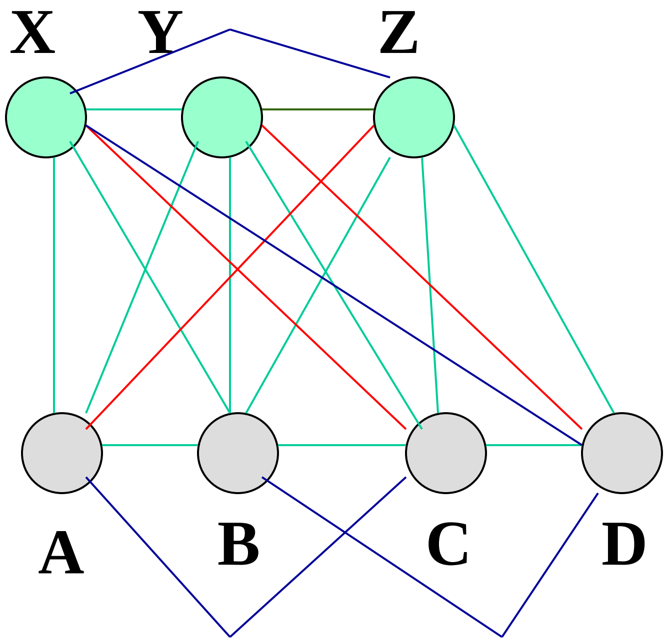
Additional problem: improvement of generation 5G
(usage of multiple choice problem)



3.9.Example: Location of employees into rooms (usage of HMMD)

APPLIED PROBLEM:
Location of 9 employees ($P_1,\ldots,P_9$) to 7 rooms (X, Y, Z, A, B, C, D)
(initial data based on German research project)





Ordinal proximity between rooms: (a) small, (b) medium (c) big

Source:
M.Sh. Levin, Combinatorial Engineering of Decomposable Systems, Springer, 1998.

Team members

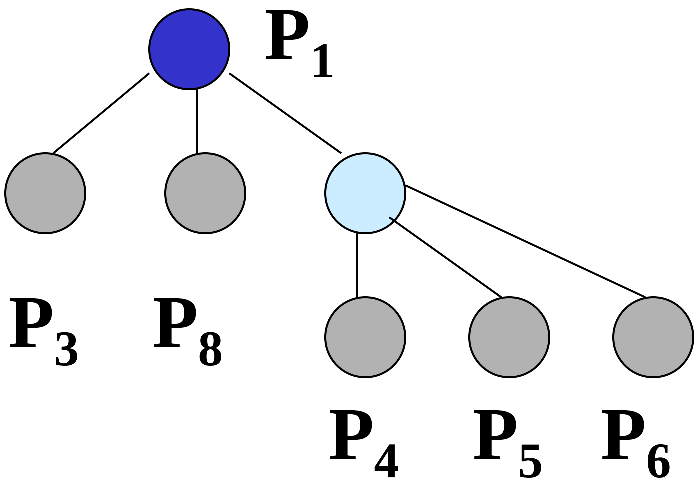
P_1 Leader of large project R_1
P_2 Leader of large project R_2
P_3 Manager of large project R_1
P_4 Researcher, projects: R_1 and R_3
P_5 Researcher, project: R_2
P_6 Researcher, projects: R_1 and R_4
P_7 Researcher, projects: R_1 and R_2
P_8 Secretary, project: R_1
P_9 Secretary, project: R_1, R_2, R_3, R_4

DESCRIPION of EMPLOYEES

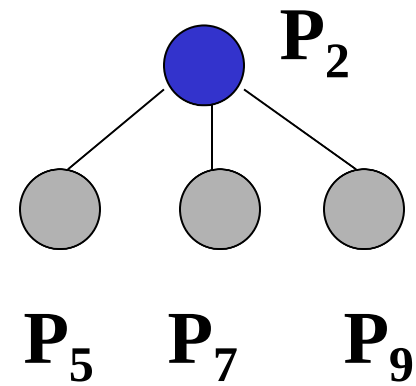
	SMOKING	FRIENDSHIP	POSSIBLE ROOMS for ASSIGNMENT
P_1	Yes	P_2 , P3	A, B, C, D
P_2	None	P_1	A, B, C, D
P_3	Yes	P_1, P_5	A, B, C, D, X, Y, Z
P_4	None	P_1, P_3, P_8	A, B, C, D, X, Y, Z
P_5	Yes	P_3, P_8	A, B, C, D
P_6	None	P_4	A, B, C, D, X, Y, Z
P_7	Yes	P_5, P_9	A, B, C, D
P_8	Yes	P_3, P_5	A, B, C, D, X, Y, Z
P_9	Yes	P_7	A, B, C, D, X, Y, Z

STRUCTURE OF PROJECTS

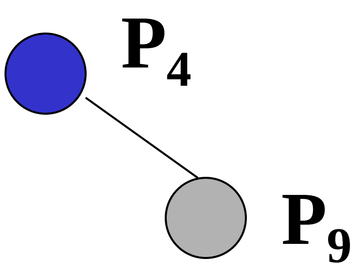
Project R_1



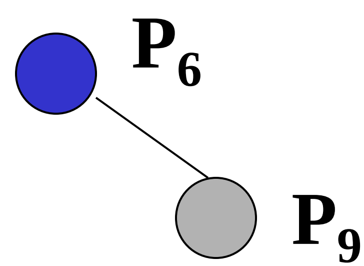
Project R_2



Project R_3



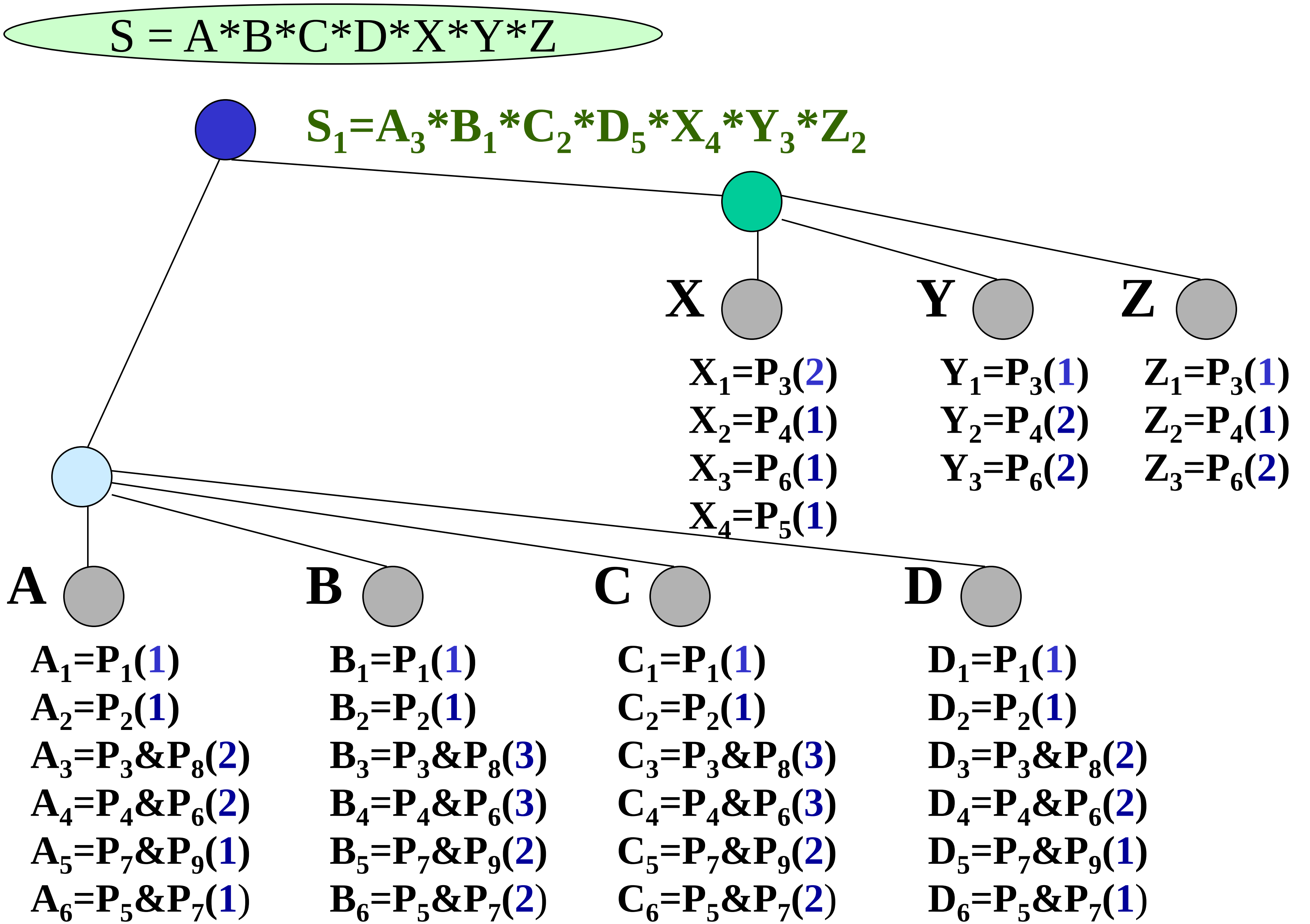
Project R_4



RULES

RULE 1: Project leader has to be located very close to members of his project
RULE 2: Project leader has to be located in big room (alone)
RULE 3: Project manager has to be located close to project leader & project secretary
RULE 4: Project manager has to be located at a small room (alone) or at the big room (for only two employees)
RULE 5: Researcher has to be located at the small room (alone) or at the big room (two employees)
RULE 6: Project members have to be located at the same room or at close rooms
RULE 7: Secretary can be located at the big room (two employees) or at the small room (two employees)
RULE 8: Smoke and non-smoke employees have to be located at different rooms
RULE 9: Friends have to be located at the same room or at close rooms

3.9.Example: Location of employees into rooms (usage of HMMD)



Location solution:

$S_1=A_3*B_1*C_2*D_5*X_4*Y_3*Z_2$

X: P_5	Y: P_6	Z: P_4

A: P_3&P_8	B: P_1	C: P_2	D: P_7&P_9

Part 4. Applied examples in education

PLAN:

4.0.Basic author’s references
4.1.Design of student plan (courses, art, sport, work)
4.2.Evolution of three modular courses, forecasting, aggregation of the results)
4.3.Design of student individual trajectory (BS->MS->PhD->PostDoc)
4.4.Examples of student projects
4.5.Publications (based on student projects)

4.0.Basic author's references

I.Books:

3.1.Levin M.Sh. Modular System Design and Evaluation, Springer, 2015.

3.2.Levin M.Sh. Composite Systems Decisions. Springer, 2006.

3.3.Levin M.Sh. Combinatorial Engineering of Decomposable Systems, Springer, 1998.

II.Papers:

3.1.Levin M.Sh. Course on system design (structural approach). Elect. Prepr., 22 p., Mar. 20, 2011; http://arxiv.org/abs/1103.3845[cs.SE]

3.2.Levin M.Sh. Course 'design of systems: structural approach'. ASME Int. Design Engineering Technical Conferences and Computers and Information in Engineering Conference (IDETC/CIE2006), Paper no. DETC2006-00547

3.3.Levin M.Sh. Discrete route/trajectory decision making. Electr. Prepr., 25 p., Aug.18. 2017; http://arxiv.org/abs/1508.03863[cs.AI]

3.4.Levin M.Sh. Student research projects in system design. Int. Conf. on Computer Supported Education CSEDU 2009, Lisbon, vol. 2, 67-72, 2009.

3.5.Levin M.Sh. Towards k-set frameworks in education. CSEDU 2011, The Netherlands, vol. 2, 99-104, 2011.

3.6.Levin M.Sh. The third literacy. Aut. Doc. & Math. Linguistics, 29(3), 66-81, 1995.

3.7.Levin M.Sh. Towards combinatorial evolution of composite systems. Expert Systems with Applications, 40(4), 1342-1351, 2013.

4.1.Design of student plan (Levin, 1998)

0.Student plan S = A*B*C*D*E:
1.Basic course(s) A = O*T*M:
1.1.OR O: $O_1 \ldots O_7$
1.2.CS T: $T_1..T_5$
1.3.Manag. M: $M_1..M_6$
2.Additional course(s) B=G*H*U*V
2.1.Engineering G: $G_1..G_7$
2.2.Psychology H: $H_1..H_5$
2.3.Languages U: $U_1..U_8$
2.4.History V: $V_1..V_6$
3.Art C=I*J*K
3.1.Dance I: $I_1..I_3$
3.2. Music J: $J_1..J_4$
3.3.Theatre K: $K_1..K_5$
4.Sport D=L*P*Q
4.1.Team game (e.g., football) L: $L_1..L_5$
4.2.Prestige game (e.g., tennis) P: $P_1..P_5$
4.3.Psysiological (e.g., box, karate) Q: $Q_1..Q_6$
5.Temporary job E=X*Y*Z
5.1.Bank X: $X_1..X_7$
5.2.University (e.g., research) Y: $Y_1..Y_5$
5.3.Company (marketing) Z: $Z_1..Z_8$

Criteria for DAs:
1.Cost/salary
2.Possibility to meet useful person(s)
3.Possibility to meet friend(s)
4.Possibility to meet boy/girl friend
5.Accordence to inclinations
6.Usefulness to future career
7.Usefulness to health
8.Usefulness to future life

4.1.Design of student career plan (Levin, 1998)

Illustrative example of student plan:

$S = A_1 * B_1 * C_3 * D_2 * E_3$

Plan parts:

$A_1 = O_5 * T_5 * M_6$

$B_1 = G_7 * H_3 * U_2 * V_2$

$C_3 = I_2 * J_2 * K_2$

$D_2 = L_5 * P_2 * Q_4$

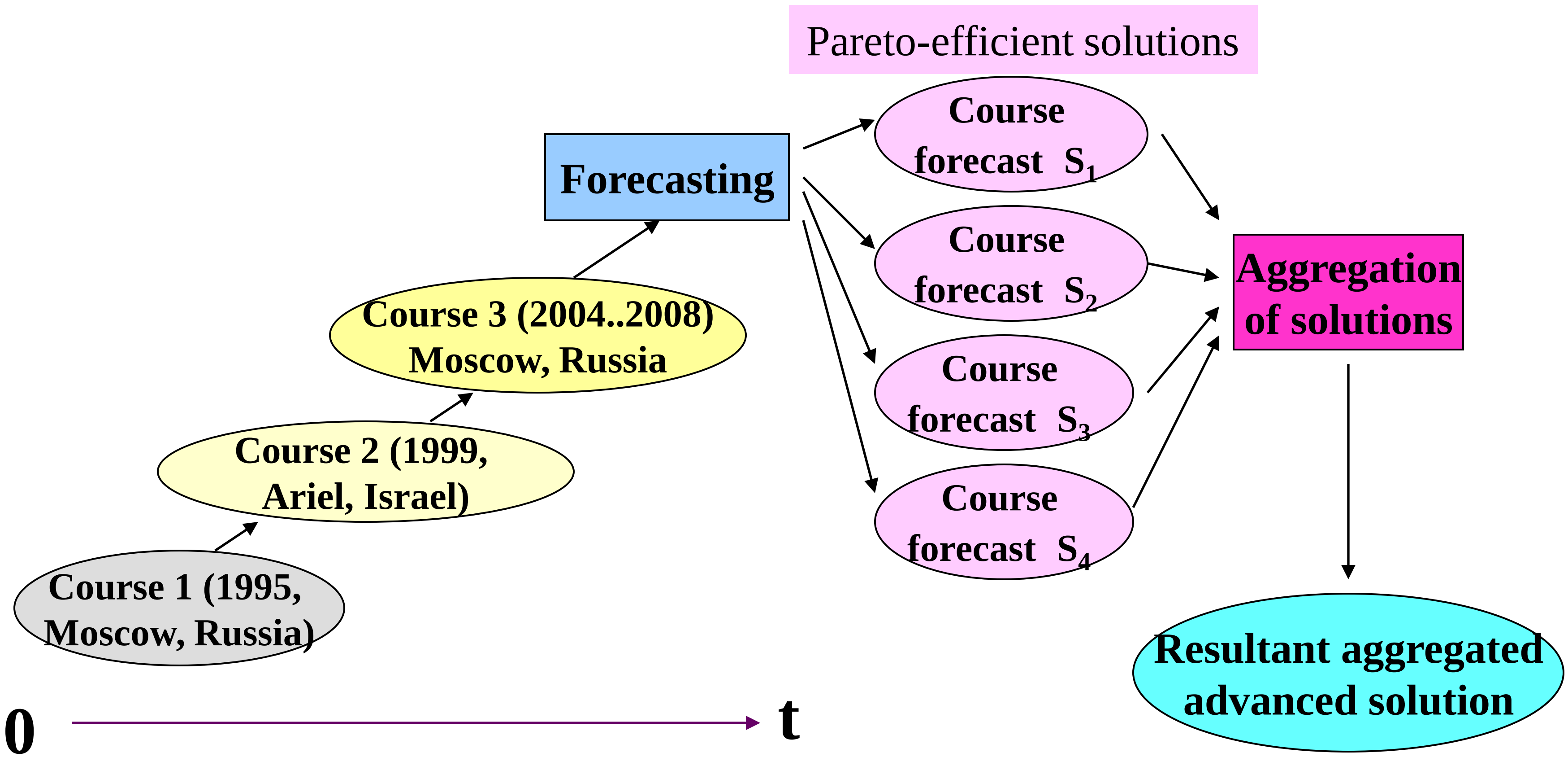
$E_3 = X_7 * Y_3 * Z_7$

Elements of solution (selected DAs):

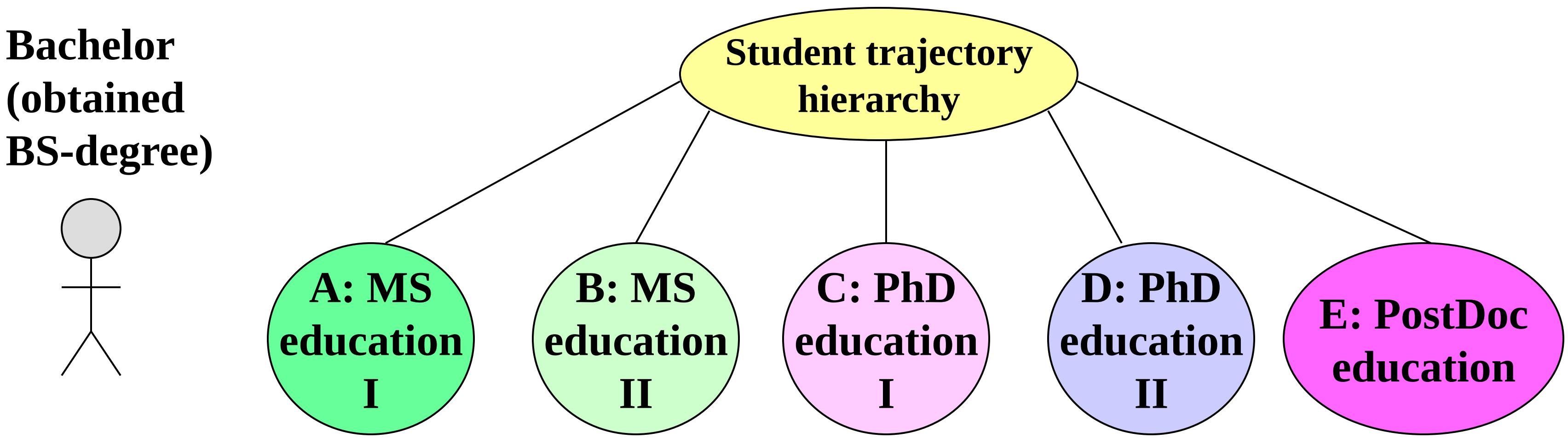
O_5 Multicriteria decision making
T_5 HCI
M_6 Project management
G_7 Software engineering
H_3 Cognitive psychology
U_2 French
V_2 Modern history
I_2 Ball dance
J_2 Classic music
K_2 Actor
L_5 Volley-ball
P_2 Tennis
Q_4 Jogging
X_7 Modeling
Y_3 Software development
Z_7 Marketing

4.2.Evolution of modular courses, forecast, aggregation (Levin, 2013)

Course 1: Information technology and decision making (1995, Moscow, Russia, Inst. for Economics, Management, Low)
Course 2: Introduction to systems engineering (1999, Ariel College, Israel)
Course 3: System design (structural approach) (2004..2008, Russia, Moscow Inst. of Physics &Technology - MIPT)



4.3.Example: Design of student individual trajectory (Levin, 2017)



A_1 (Univ. 11)	B_0 (None)	C_1 (Univ. 31)	D_0 (None)	E_1 (Univ. 1)
A_2 (Univ. 12)	B_1 (Univ. 21)	C_2 (Univ. 32)	D_1 (Univ. 41)	E_2 (Univ. 2)
A_3 (Univ. 13)	B_2 (Univ. 22)	C_3 (Univ. 33)	D_2 (Univ. 42)	E_3 (Univ. 3)
A_4 (Univ. 14)	B_3 (Univ. 23)	C_4 (Univ. 34)		E_4 (Univ. 4)
		C_5 (Univ. 35)		

Parameters of DAs:
1.Time
2.Cost (or complexity)
3.Quality of education
3.Prestige

Objectives:
1.Total cost
2.Total time
3.Total results
(e.g., prestige)

Examples of solutions:
$T_1 = \langle A_2, B_3, C_4, D_1, E_3 \rangle$
$T_2 = \langle A_1, B_0, C_5, D_0, E_4 \rangle$
$T_3 = \langle A_3, B_2, C_1, D_0, E_2 \rangle$

4.4.Examples of student projects

Examples of student projects:

1.Multicriteria Steiner tree problem for communication networks
2.Connection of users with a telecommunication networks: multicriteria assignment problem (selection/allocation of access points)
3.Improvement of regional telecommunications networks
4.Modular redesign of networked system
5.Configuration of alarm wireless sensor element
6.Design of modular wireless sensor
7.Composition of structure of the telemetry system (unmanned vehicle)
8.Composite combinatorial scheme of test planning (for microprocessor systems)
9.Plan of modular marketing
10.Configuration of integrated security system

4.5.References – Student papers based on student projects

Student papers based on student projects (laboratory works, BS theses, MS theses)

1.Levin M.Sh., Zamkovoy A.A. Multicriteria Steiner tree with the cost of Steiner vertices. J. of Commun. Technol. & Electr., 56(11), 1527-1542, 2011.

2.Levin M.Sh., Nuriakhmetov R.L. Multicriteria Steiner tree problem for communication network. Electr. prepr., 11 p., Feb. 12, 2011; http://arxiv.org/abs/1102.2524[cs.DS]

3.Levin M.Sh., Petukhov M.V. Connection of users with a telecommunication network: multicriteria assignment problem. J. of Commun. Technol. & Electr., 55(12), 1532-1541, 2010.

4.Levin M.Sh., Petukhov M.V. Multicriteria assignment problem (selection of access points). Proc. of 23rd Int. Conf. IEA/AIE 2010, LNCS 6097, part II, Springer, 277-287, 2010.

5.Levin M.Sh., Safonov A.V. Improvement of regional telecommunications networks. J. of Commun. Technol. &Electr., 56(6), 770-778, 2011.

6.Levin M.Sh., Safonov A.V. Towards modular redesign of networked system. 2nd Congress ICUMT-2010, Moscow, 109-11, 2010.

7.Levin M.Sh., Fimin A.V. Configuration of alarm wireless sensor element. 2nd Congreee ICUMT-2010, Moscow, 924-928, 2010.

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5.Conclusion: A.Application domains

I.Computer systems:

(a)synthesis of modular software package

(b)human-computer interface (DSS COMBI)

(c)overlay structure of modular software

(d)series-parallel strategies for multicriteria ranking (DSS COMB)

II.Biomedicine: (a)treatment plan (b)immunological analysis

III.Civil engineering: (a)building (b)concrete technology

IV.Communication systems, sensor networks, telemetry systems:

(a)allocation of end users (last mile problem)

(b)standard for multimedia information transmission (MPEG)

(c)protocol for sensor networks ZigBee (d)radio sensor

(e)telemetry system (f)regional communication network

(g)generations of wireless mobile systems

V.Control and management:

(a)modular control system for smart home (b)integrated security system

(c)modular planning in geological exploration (d) planning of marketing

VI.Education:

(a)synthesis/evolution of course

(б)synthesis of student plan/student trajectory

5.Conclusion: B.Systems results

1.Systematization of decision support for stages of life cycle:
Modular systems with morphological model

2.Examination and design of
typical combinatorial engineering frameworks
for decision support комбинаторных (7+1)

3.New morphological synthesis (modular design)
'Hierarchical Morphological Multicriteria Design' HMMD

4.Library of applied problem-prototypes (basic analogues)

5.Conclusion: C.New problems, models, algorithms

1.New combinatorial optimization model 'morphological clique'
2.New hierarchical knapsack problem and new polynomial approximate algorithm (PTAS-like))
3.New vector-like proximity measure for rankings
4.Design of series-parallel solving strategies based on HMMD (example for DSS COMBI)
5.New location problem/scheme based on HMMD
6.New type on interval multiset-like estimate and operations over it
7.New type of combinatorial optimization problem with objective function as maximum of median (problems: multiple choice problem, knapsack, assignment, morphological clique)
8.New approach to data integration based on clique fusion over graph stream
9.New approach for solution restructuring for combinatorial optimization problems (knapsack, multiple choice problem, clustering)

5.Conclusion: D.Application in education

1.Educational courses based on HMMD (and their implementation)

2.Basic problems:
2.1.design of modular course
2.2.planning of student career
2.3.design of educational environment
2.4.combinatorial evolution of educational modular course
2.5.design of student individual trajectory

END

GR8 THANKS!