노드-링크 관점을 이용한 가입자 통신망 설계에 관한 연구

김 철 수*, 이 재 규**

* 원광대학교 정보관리학과
570-180, 전북 익산시 신용동 원광대학교

** 한국과학기술원 테크노경영대학원
130-012 서울시 동대문구 청량리동 207-43

요 약

기존의 지식기반 모델링 시스템인 UNIK-OPT는 선형과 정수계획 모형을 모델, 제약식, BOT(Block of Terms), 변수 그리고 계수로 정의하고 이들을 사용하여 수리계획 모형을 의미론적인 관점에서 표현하고 있다. 본 연구에서는 그 시스템을 가입자 통신망 설계로 확장하기 위해서 노드-링크 관점으로 네트워크 모형을 표현하고 이를 다시 UNIK-OPT 시스템 내의 표현으로 변환시키는 데에 초점을 맞추고 있다.

먼저 가입자 통신망의 특성을 5가지 차원으로 분류하였으며, 그 차원들은 OBJECTIVE, NODE, LINK, NODE-LINK, VARIABLE 등이며, 각각의 차원을 관련된 항목드로 자세히 표현하였다. 그리고 5가지 차원으로 구성된 노드-링크 관점으로 표현되어진 모형을 다시 의미론적인 관점으로 변환시키는 과정을 제시하고 있다. 또한, 도메인 정보를 가지고 있는 사용자가 설계하고자 하는 모형을 노드-링크 관점으로 받아들이기 위해서 모형추론과정을 제안하고 있다. 그리고 제안된 이론을 프로토타입 HLR-LACN (High Level Representation-Local Access Communication Network) 의 전반적인 아키텍처를 제시하고 있다.

A Designing System of Local Access Communication Network Using Node-Link Views

*Chulsoo Kim and **Jae Kyu Lee

*School of Business Administration, Wonkwang University,
344-2, ShinRyong-Dong, Iksan-si, Chollabuk-Do, 570-749, Korea
e-mail: cskim7@wonnms.wonkwang.ac.kr

**Graduate School of Management,
Korea Advanced Institute of Science and Technology, 207-43,
Cheongryang, Seoul, 130-012, Korea
e-mail: jklee@msd.kaist.ac.kr

Abstract

UNIK-OPT, the first version of optimization UNIK system, is a knowledge-assisted optimization model formulator. It covers the linear and integer programming model and represents the models with a semantic view. This research intends to improve this tendency by extending its scope of application to the design of local access communication networks (LACNs). Most of users tend to look at the network model specification in terms of a node-link view rather than mathematical notation or semantic view of UNIK-OPT. In particular, it tries to extract representations of a node-link view having structural characteristics from LACNs.

*This research is to provide the model builders a node-link view using five distinctive characteristics : OBJECTIVE, NODE, LINK, NODE-LINK, and VARIABLE. We define the representation of each characteristic relevant to design of LACNs. In addition, each of the representation is converted into one of semantic view, the one converted is connected with the solvable heuristic algorithm. For designing LACNs, the formulation reasoning process is proposed. A system HLR-LACN (**High Level** Representation - Local Access Communication Network) is developed to implement this approach.*

1. Introduction

In an effort to establish the national information infrastructure, the recent growing interest resides in requiring an analytic and systematic framework for an efficient implementation of a variety of communication network models. In this context, there is a need for the implementation frequently occured during the whole network life-cycle : design, management, expansion, and evolution. And corporations have discovered how to use communication-based system and computer networks as a strategic competitive weapon. Modern computer networks are composed of 1) backbone networks serving as major highways to transfer large volumes of communication traffic, and 2) local access networks feeding traffic between the backbone

PCL XL error

Subsystem: KERNEL

Error: IllegalStreamHeader

Operator: 0x0

Position: 0

$$Minimize \quad \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij} \quad ;............(1)$$

subject to

$$\sum_{i=1}^{m} a_{ij}x_{ij} \le b_j, \quad j = 1,...,n \quad ......(2)$$

$$\sum_{j=1}^{n} x_{ij} = 1, \quad i = 1,...,m \quad ....(3)$$

$$x_{ij} = \{0,1\} \quad \forall_{i,j} \quad ......(4)$$

We can represent this problem using the semantic view of UNIK. The semantic view specifies the optimization model using formal knowledge representation such as frames (Lee and Kim, 1995). Figure 1 is a frame representation of plant assignment problem.

<Figure 1> appears about here

The UNIK-OPT supports three levels of views: semantic, notational (aggregate or individual equational), and tabular views. The model shown in (1)-(4) corresponds to an aggregate notational view. Semantic view should at least include more information than notational view so that the semantic view can be transformed to the notational view without any ambiguity. In UNIK-OPT, the semantic network model is represented by objects, which can be automatically transformed to the mathematical notational form.

By using the structural characteristic of network models, a specific model object can be decomposed to a set of Blocks Of Terms (BOTs) and inequality (or equality) operator.

The BOT means a pair of constant and variable that shares the same "Σ" sign. Special types of BOT are terms with only constant and those with null summation indices. In turn, the attribute and index object can be represented by their associations. The UNIK-OPT supports such an object-orientation representation of the network model and the knowledge-based formulational aid [Lee and Kim, 1995; Kim and Lee, 1996].

3. Node-Link Views for Network Models

In the network model, Most of users tend to look at the network model specification in terms of a node-link view rather than mathematical notation or semantic view of UNIK-OPT. This section shows five distinctive characteristics: OBJECTIVE, NODE, LINK, NODE-LINK, and VARIABLE for the node and link representation. Figure 2 shows node and link representations for the network model (1)-(4).

<Figure 2> appears about here

The key issues in designing the network model are the analysis of node-link relations and transformation of the node-link view to the semantic view for being operated in UNIK-OPT system. We represent the problem of figure 2 as follows:

{{ plant_assignment_problem
    IS-A : NETWORK_MODEL
    OBJECTIVE : *MinimumCost* ----- (5)
    NODE : *NodeCluster_2, NodeValue* ----- (6)
    LINK : *LinkDirection, LinkSetupFlow*----- (7)
    NODE-LINK:
        Destination_Capacity_LinkSetupFlow,

Source_Balance_1 ----- (8)

VARIABLE : *AssignmentVariable* ----- (9)

}}

We call representations (5)-(9) *node-link views or node-link representations* in network model design. Now let us show that two representations, (1)-(4) and (5)-(9), are identical. Meaning between (5) and (1) showed equal, and *NodeCluster_2, NodeValue, Destination_Capacity_LinkSetupFlow*, and *LinkSetupFlow* in node-link representations mean constraint inequality (2). *Source_Balance_1* in (8) represents constraint equation (3). The binary of VARIABLE in (9) showed equal to (4). Therefore, local access network can be represented by NETWORK_MODEL frame using five distinctive characteristics: OBJECTIVE, NODE, LINK, NODE-LINK, and VARIABLE.

3.1 Representations of OBJECTIVE Characteristics

The OBJECTIVE characteristics can be classified as follows:

- ***MinimumCost_[setup]*** : This objective function is occurred in capacitated minimal spanning tree problem (CMST) and matching problem, and [setup] term representing setup cost is optional. The cost term have a lot of meanings such as average traffic delay and risk rate in network.
- ***MaximumFlow*** : This objective function represents maximum of traffic flown in capacitated links of communication network.

3.2 Representations of NODE Characteristics

The NODE characteristics can be represented as a lot of meanings such as backbone nodes or user nodes in the communication network model. The characteristics can be classified as follows:

- ***NodeCluster_n***: node set is divided by n groups: source, sink, intermediate, etc.
- ***NodeCost***: all nodes have setup cost term.
- ***NodeValue***: some nodes of the node set have just one characteristic among capacity, requirement, and balance.
- ***NodeReliability***: there exists reliability term in some nodes.
- ***NodeCenter_n***: there exists n center in node set.
- ***NodeTraffic***: there exists traffic needed between a origin and a destination in some nodes.

3.3 Representations of LINK Characteristics

Let us not consider whether the lines of LACN are wire and wireless. The characteristic can be classified as follows:

- ***LinkDirection***: there exists a direction in some links.
- ***LinkCost***: all links have cost term.
- ***LinkCapacity***: the amount of flow is restricted to lower and upper bounds for each of links.
- ***LinkSetupFlow***: there exist setup flows in some links.

- ***LinkMultipleFlow***: there exist multiple flows for each of links.

3.4 Representations of NODE-LINK Characteristics

In the network model, it is important to represent relationships between NODE and LINK rather than their informations for describing the model in detail. For instance of LACNs, we show the following three illustrative ones. A general format is:

(Source/Destination)_(Capacity/Requirement/Balance)_[1/2]_[LinkSetupFlow]_ [Conservation]

Least one term in a parenthesis must be chosen and it is optional about terms in a bracket.

- ***Source_Balance_1***: out-flow from a node is just one for all node..
- ***Source_Balance_Conservation***: amount of difference between in-flows and out-flows for each of nodes follows conservation equation.
- ***Source/Destination_Capacity_Setup***: all links are limited to predetermined amount for each of links. .

3.5 Representations of VARIABLE Characteristics

The characteristic of VARIABLE includes ***binary*** (or ***AssignmentVvariable***), ***real_number*** (or ***FlowVariable***), and ***general_integer_variable***.

4. Transformation of Node-Link view into Semantic View

Our next concern is the transformation of node-link view into semantic representations: model frame, constraint frame, BOT frame, attribute frame, and index frame. Now let us see how we can automatically transform node-link representations into semantic representations. Let's consider a node-link formulation of the plant_assignment_problem in (5) - (9). This model is one of generalized assignment problems. The model is represented by OBJECTIVE slot having one slot value, NODE slot having two, LINK slot having two, NODE-LINK slot having two, and VARIABLE slot having one as shown in section 3. Overall approaches of transformation is processed by top down reasoning method, that is, starting to transformation of model frame. For the semantic representation, refer to Figure 1.

4.1 Transformations of Node-Link Views into Model frame

DIRECTION and OBJECTIVE slot values of the semantic representation are determined by *MinimumCost* of OBJECTIVE in (5). And destination_capacity_linksetupflow_constraint and source_balance_constraint are resulted from two slot values of NODE-LINK in (8).

4.2 Transformations of Node-Link Views into Constraint frame

For generation of two constraints, destination_capacity_linksetupflow_constraint and *source_balance_constraint*, *Destination_Capacity_LinkSetupFlow* of NODE-LINK in (8) determines *destination_capacity_linksetupflow_constraint* of semantic representations as follows:

- OPERATOR : LE <– Capacity in (8) —— (10)
- LHS : (+ *source_sum_BOT*) <– Destination in (8) —— (11)
- RHS : (+ *destination_capacity_BOT*) <– *LinkSetupFlow* in (8) —— (12)
- UNIT_INDEX : *destination* <– *Destination* in (8) —— (13)

Source_Balance_1 of NODE-LINK in (8) determines *source_balance_1_constraint* of semantic representations as follows:

- OPERATOR : EQ <– *Balance* in (8) —— (14)
- LHS : (+ *source_choice_BOT*) <– *Source* in (8) —— (15)
- RHS : (+ *one_BOT*) <– 1 in (8) —— (16)
- UNIT_INDEX : *source* <– *Source* in (8) — (17)

4.3 Transformations of Node-Link Views into BOT frame

For five BOT frames, *total_cost_BOT*, *source_choice_BOT*, *source_sum_BOT*, *one_BOT*, *destination_capacity_BOT*, showed fore subsections, this subsection describes the generation of the five frames using node-arc representations (5)-(9). First, generation of *total_cost_BOT* frame is explained as follows:

- ATTRIBUTE : *unit_cost assignment_var* <– *minimum_cost* in (5)
- SUMMATION_INDEX : *source destination* <– *minimum_cost* in (5) and nature of network model

Second, *source_choice_BOT* frame is generated as follows:

- ATTRIBUTE : *one assignment_var* <– *Source* in (8)
- SUMMATION_INDEX : *destination* <– INDEX set - UNIT_INDEX set = {*source*, *destination*} - {*source*} = {*destination*}

Third, source_sum_BOT frame is generated as follows:

- ATTRIBUTE : *destination_volume assignment_var* <– *LinkSetupFlow* in (7)
- SUMMATION_INDEX : *source* <– INDEX set - UNIT_INDEX set = {*source*, *destination*} - {*destination*} = {*source*}

Fourth, one_BOT frame is generated as follows:

- ATTRIBUTE : *one* <– *1* in (8)
- SUMMATION_INDEX : null

Finally, *destination_capacity_BOT* frame is generated as follows:

- ATTRIBUTE : *destination_capacity* <– *LinkSetupFlow* in (8)
- SUMMATION_INDEX : null

4.4 Transformations of Node-Link Views into ATTRIBUTE frame

Generally, for well known network model, most of ATTRIBUTE frames are predetermined by characteristics of coefficients and variables. For examples of this problem, *assignment_variable* of VARIABLE has source and destination of

LINKED_INDEX. For frames of the COEFFICIENT, because *the unit_cost* are occurred in a objective function, LINKED_INDEX of it have all indices, and one frame don't have any index. For *destination_volume* and *destination_capacity*, each of them is influenced by occurrence of left hand side or right side hand and the characteristic of constraint frames such *LinkSetupFlow* and *Capacity*.

4.5 Transformations of Node-Link Views into INDEX frame

All INDEX frames are induced by LINKED_INDEX of attribute frames by the other way.

5. Formulation Reasoning Process for Designing Local Access Networks

The formulation reasoning process is based on the knowledge representation scheme developed in section 3. This process is to minimize the designer's input burden. So, we proposed seven steps for formulating the local access network model. For showing formulation reasoning process, let us examine theses steps with telepak problem shown in Figure 3.

<Figure 3> appears about here

Step 1. Select decision variable of problem type, such as facility location problem, route selection problem, and flow analysis problem, etc.

[Example]

The telepak problem belong to composite one, associated flow analysis problem with route selection problem. So, decision variable type are *AssignmentVariable* and *FlowVariable*.

- VARIABLE : ***AssignmentVariable, FlowVariable***

Step 2. Select number of node group divided.

[Example]

Since node set of the problem is divided by center set and terminal set, number of node group is two.

- NODE : ***NodeCluster_2***

Step 3. Determine characteristics of node set.

[Example]

The problem have one center and many terminals, each of terminal nodes generate amount of flows predetermined.

- NODE : ***NodeCenter_1, NodeValue***

Step 4. Determine characteristics of link set.

[Example]

All links of the problem have upper limit on line capacity.

- LINK : ***LinkCapacity***

Step 5. Provide the data values.

[Example]

- Data values to be input : ***fixed setup cost, flow cost, traffic generated by terminals, upper limit on all lines***

Step 6. Select objective function.

[Example]

- OBJECTIVE : ***MinimumCost_Setup***

Step 7. Determine relationships between node and link

[Example]

- NODE-LINK : ***Source_Balance_1, Source_Balance_Conservation, Source/Destination_Capacity_Setup***

Node-link representations of the problem resulted from above procedure are shown as follows:

{{ telepak_problem

IS-A : NETWORK_MODEL

OBJECTIVE : *MinimumCost_Setup*

NODE : *NodeCluster_2, NodeCenter_1, NodeValue*

LINK : *LinkCapacity*

NODE-LINK:

Source_Balance_1

Source_Balance_Conservation1

Source/Destination_Capacity_Setup

VARIABLE:*AssignmentVariable, FlowVariable*

}}

6. Conclusion

To implement the formulation reasoning process and transformation of a node-link view into semantic view, we are developing a prototype HLR-LACN. The overall architecture of HLR-LACN is depicted in Figure 4. The system includes the key processors - "Formulation" for the formulation reasoning process and "Transformation" for the transformation of a node-link view into a semantic view explained in the earlier sections. Furthermore, the Algorithm Selector identifies the structure of the network model, and connects with the adequate algorithm for solving the model.

<Figure 4> appears about here

A prototype HLR-LACN is developed using the UNIK environment. The relevant capabilities employed from UNIK are objects (UNIK-OBJECT), forward chaining (UNIK-FWD) for transforming it into a semantic view, and linear and integer programming (UNIK-OPT) model representation aid [Lee and Song, 1995; Lee et. al., 1994].

This research has shown that the node-link view includes five characteristics needed for designing LACN, the transformation of a node-link view into a semantic view, and formulation reasoning process for acquiring the node-link view from user's domain can be accomplished. This work should contribute to the representation in a higher level of particular domain knowledges, relevant to the communication networks.

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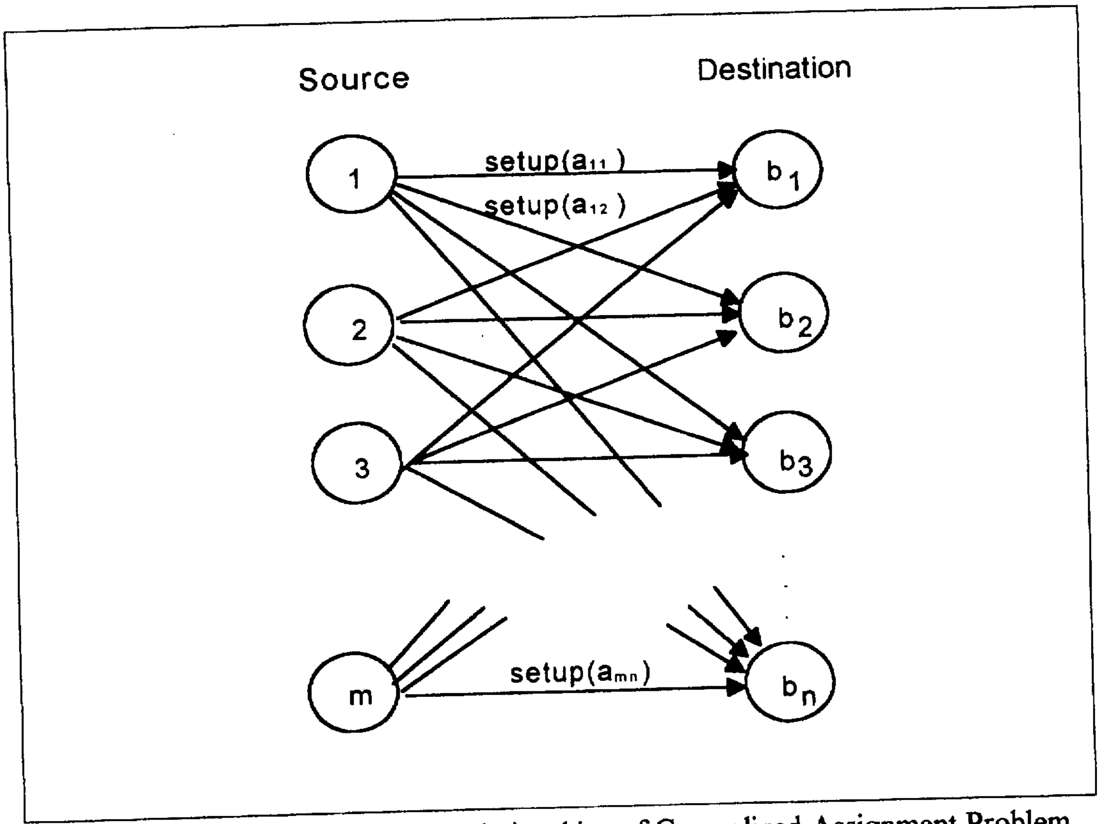
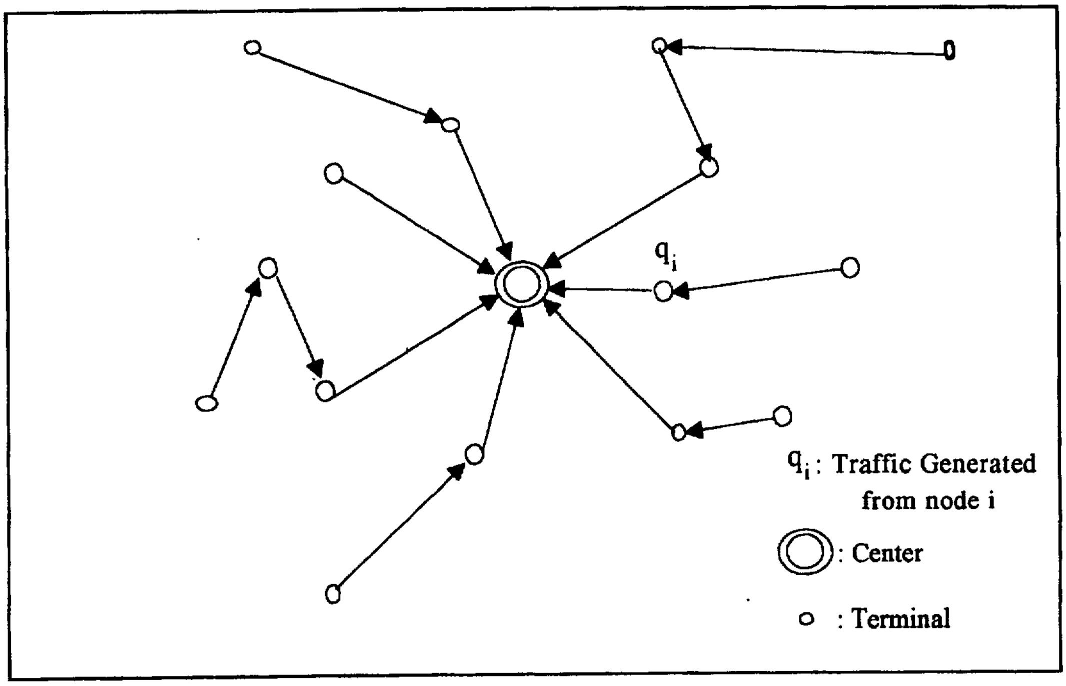
{{ plant_assignment_problem
      IS-A : NETWORK_MODEL
      DIRECTION : min
      OBJECTIVE : (+ total_cost_BOT)
      CONSTRAINT : destination_capacity_constraint
                   destination_assignment_constraint}}
{{ destination_capacity_constraint
      IS-A : CONSTRAINT
      OPERATOR : LE
      LHS : (+ destination_sum_BOT)
      RHS : (+ destination_capacity_BOT)
      UNIT_ INDEX : destination }}
{{ destination_assignment_constraint
      IS-A : CONSTRAINT
      OPERATOR : EQ
      LHS : (+ destination_choice_BOT)
      RHS : (+ one_BOT)
      UNIT_INDEX : source }}
{{ total_cost_BOT
      IS-A : BOT
      ATTRIBUTE : unit_cost assignment_var
      SUMMATION_INDEX : source destination }}
{{ destination_sum_BOT
      IS-A : BOT
      ATTRIBUTE : destination_volume assignment_var
      SUMMATION_INDEX : source }}
{{ destination_capacity_BOT
      IS-A : BOT
      ATTRIBUTE : destination_capacity
      SUMMATION_INDEX : }}
{{ destination_choice_BOT
      IS-A : BOT
      ATTRIBUTE : one assignment_var
      SUMMATION_INDEX : destination }}
{{ one_BOT
      IS-A : BOT
      ATTRIBUTE : one
      SUMMATION_ INDEX : }}
{{ assignment_var
      IS-A : VARIABLE
      SYMBOL : x
      LINKED_INDEX : source destination
      TYPE : binary }}
{{ unit_cost
      IS-A : COEFFICIENT
      SYMBOL : c
      LINKED_INDEX : source destination }}
{{ destination_capacity
      IS-A :COEFFICIENT
      SYMBOL : b
      LINKED_INDEX : destination}}
{{ source
      IS-A : INDEX
      SYMBOL : i
      LINKED_ATTRIBUTE : assignment_var
        unit_cost destination_volume}}
{{ destination_volume
      IS-A : COEFFICIENT
      SYMBOL : a
      LINKED_INDEX : source destination }}
{{ one
      IS-A :COEFFICIENT
      SYMBOL : 1
      LINKED_INDEX : }}
{{ destination
      IS-A : INDEX
      SYMBOL : j
      LINKED_ATTRIBUTE : assignment_var
        unit_cost destination_volume destination_capacity}}
```

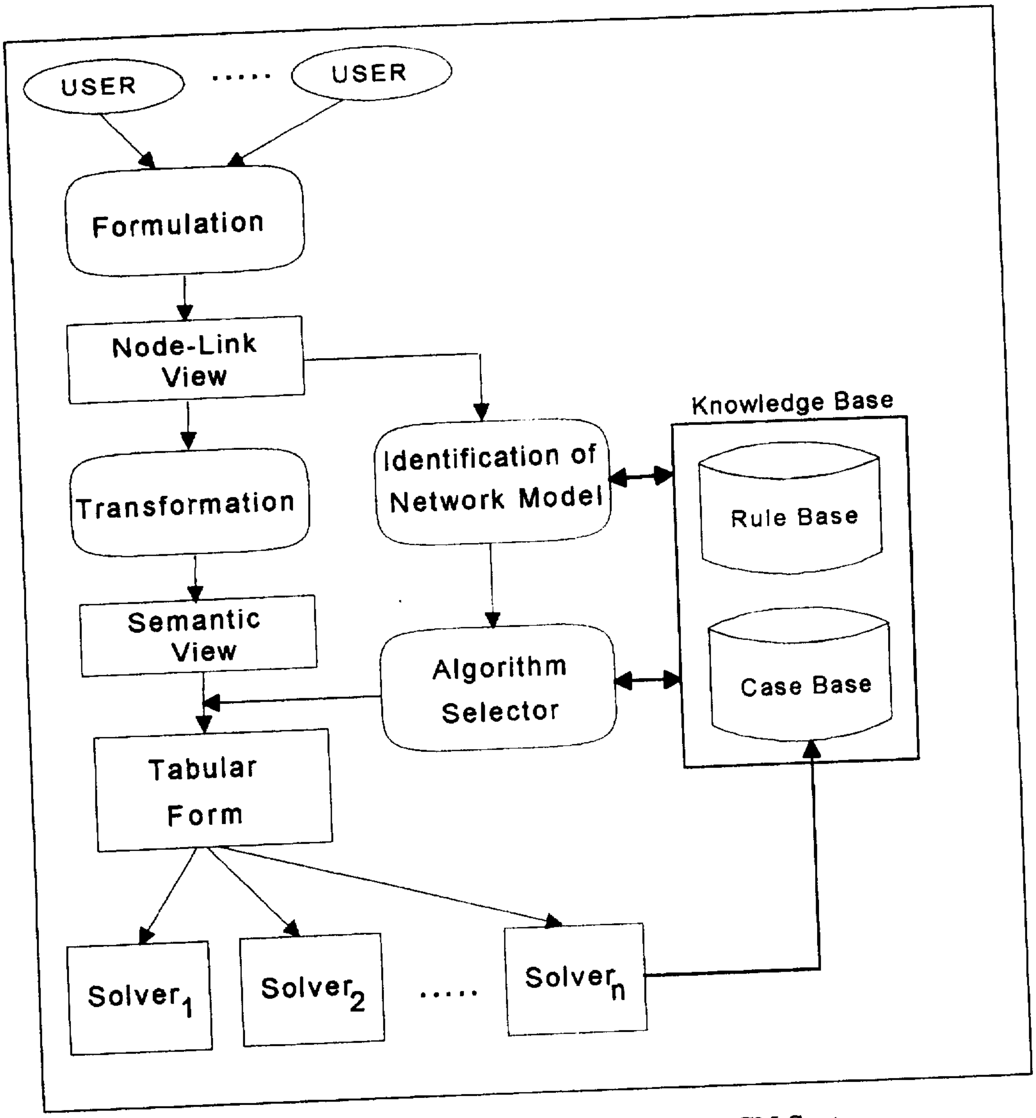
<Figure 1> Frame Representation of Plant Assignment Problem in the UNIK-OPT Syntax



<Figure 2> Node-Link Relationships of Generalized Assignment Problem



<Figure 3> Node-Link Relationships of Telepack Problem



<Figure 4> Overall Architecture of HLR-LACN System