PLANET: A Tool for Telecommunication Network Planning and its Applications in Hungary

L. Jereb, T. Jakab, M. Telek, A. Sipos, and G. Paksy

***Abstract*—PLANET is an integrated software package aiding several steps of the transmission network planning, as well as the traffic simulation. The database of PLANET consists of the structural and the cost models of the transmission systems, the topological alternatives, the circuit routing and grouping rules, etc. The topological and transmission plans of the networks are obtained based on the traffic planning results checked by simulation and they are stored systematically with the input data in the database of plans. The results describe the network topology, the circuit routes meeting different kinds of routing conditions, the grouping solutions and the equipment assignments to the circuit demands of different services. The users of PLANET are provided with lists and graphical documentation that can be directly used in the development of the network. The global structure of the software package as well as the algorithms of specific phases are discussed and the results obtained by the application of PLANET are demonstrated.**

I. Introduction

THE preliminary steps towards the establishment of PLANET were taken about 15–20 years ago, when the first traffic planning packages were developed at the research institute of the Hungarian PTT [1], [2]. The Technical University of Budapest (TUB) joined these activities in 1979. The first program packages developed at TUB aimed at solving the long-term topological planning issues [5] and they were based on Minoux's results [3], [4].

Since 1986 the digitalization of the Hungarian transmission network has been carried out and the Institute of Communication Electronics of TUB has taken an active part in the determination of the digital target network.

After this common experience, the development of PLANET (PLAnning of communication NETworks) was started in 1989 and it has been applied in network planning at the PKI Telecommunication Development Institute of Hungarian Telecom Company (PKI–TDI) since 1991.

The rest of the paper is organized as follows. In Section II, the basic planning objectives and the requirements of software development are summarized. The architecture of PLANET is introduced from the user's point of view in Section III. In the following two sections the basic planning phases (topological optimization and circuit routing in Section IV and grouping and equipment assignment in Section V) are discussed in detail. In Section VI, the main planning processes are introduced; in Section VII some applications of PLANET are mentioned. Finally, in Sections VIII and IX, the ongoing developments are listed and the paper is concluded.

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II. Planning Objectives

The objective of the transmission network planning phase is to find the optimal network development taking into account the increase and changing of the circuit demand, the available transmission media and equipment in the given time and in the future, as well as the technical and geographical constraints. This planning aim requires a long-term vision of the network and the determination of a development scenario at the same time.

The aim of PLANET is to assist the planners of interurban and metropolitan area trunk networks in this planning process where the long-term, medium-term, and short-term planning steps compose consecutive and consistent activities.

The long-term (10–15 years) plans basically determine the target network and define strategic plans considering the actual planning issues (digitalization, introduction, and deployment of SDH, etc.). The medium-term (3–5 years) plans identify the steps towards the target network while the short-term (1–2 years) plans are directly applied to the preparation of investments of the near future taking into account the actual technological and financial opportunities and constraints.

The complexity of the network planning necessitates the partition of the planning process even in the case of more powerful computer tools so the planning activities that must be aided cover a great number of steps including the traffic planning, the topological optimization, the circuit routing, the circuit grouping, and the equipment assignment as well as the documentation of the planning results.

The basic requirement determining the development of PLANET has been the realization of the whole planning process in an integrated frame which makes it possible to improve the planning and analysis tools in a step by step manner.

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The opportunities in Hungary in the 1980s and the possible application of PLANET at PKI–TDI have led to the PC-based implementation of the software package.

The planning process includes not only a series of consecutive planning steps, but in order to evaluate different scenarios, it must provide the planner with a great number of results corresponding to different conditions and solutions of the given planning issues or steps. A consequence of this planning feature is that the handling of the different planning alternatives and the great number of planning steps, as well as the presentation of results and planning conditions involves a lot of programs, files, and numerical and graphical results which must be handled in all phases of the planning process. In order to rid the planner of the computer application questions the menu-driven, window-based, and hidden-file access software realization has been decided.

III. The Architecture of PLANET

In order to fulfill the aforementioned requirements, PLANET consists of five major elements. These elements can be identified as database, planbase, network modelling, transmission planning and network analysis functions. The connections among them are visualized in Fig. 1. Three different components must be distinguished concerning the PLANET architecture. The first one is the central role of the modeling, the second one is the information organized into two groups of data describing the planning inputs and results, and finally, the third one is the activities of user divided into planning and analysis works.

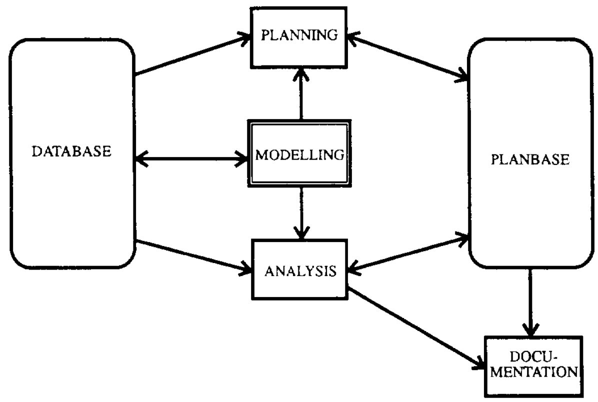

Fig. 1. The architecture of PLANET.

A. Database

The database comprises the data that are used for the construction of several network models. The database is formed by the following types of data:

- equipment type and data,
- cost models of transmission lines,
- node (demand termination and transmission points) data,
- topology,
- grouping levels, grouping rules,
- routing rules.

The database allows the user to define inputs that can be generally used in several planning steps. Naturally, the PLANET frame helps the adequate application of the different input data in every planning and analysis phase. The correct choice of database elements is assured by special parameters as technology (eg., analog, digital, mixed) and application field (e.g., Budapest, interurban) associated with each database elements.

B. Planbase

The planbase defines a plan hierarchy of three levels: plangroups, plans, and plan versions. The plangroups refer to the type of plans as "interurban," "Budapest," etc., so the inputs of a plangroup can be chosen only from a given part of the database. The plans are based on the same node lists in order to avoid the confusion of the input data of different origin, so the plans can be used for the investigation of the possible scenarios. Finally, the plan versions comprise the inputs and results of different studies of the same planning problem with similar input data.

In the planbase, this hierarchy and the new elements of this hierarchy are stored without the user's interaction, since because of the hidden files the users can access them only through properly defined interfaces. The textual and graphical documentation of every plangroup, plan, or plan version can be produced independently from the planning process.

C. Traffic Data Preparation

In the recent version of PLANET, the traffic planning step is carried out by other program packages which are not implemented within the frame PLANET planbase, the circuit demand of different services are taken into account as fix values in different units (e.g., 2Mbps, 34Mbps). During the traffic data preparation, the combined circuit demand is determined, and the further topological and transmission planning steps are based on these input data.

D. Transmission Planning

The transmission planning phase comprises the topological planning, the routing, the grouping, and the equipment assignment steps. The input data of these steps are the circuit demands generated by the traffic planning phase, the geographical constraints (rivers, mountains, etc.) given by the possible edges of the network, the cost models of the nodes and the (optical and microwave) transmission lines, the routing rules (safety requirements) for every demand class (telephone, data, etc.) and the grouping rules. The results provided by this phase are the network topology, the routes of the circuits, the grouping (multiplexing) of circuits, and the assignment of equipment to the demands. All the results can be obtained in a textual and graphical form.

E. Network Analysis

According to the principal functions of PLANET, there are planning utilities which make it possible for the user to check the results of each planning step. This analysis part is composed of the traffic plan evaluation (simulation and analytical methods) and of the reliability qualification.

Up to now, only the traffic simulation tool has been implemented in the frame of PLANET, although there are existing programs for reliability, dependability analysis of transmission network, and for traffic analysis. The first one is composed of the state-space generation of a truncated reliability model, for the calculation of reliability parameters supposing the Markov property as well as for bounding network reliability parameters [7]. The traffic analysis program calculates the traffic loss of the hierarchical traffic routing system.

The simulation part of PLANET is based on OMNET (objective modular network testbed), a general purpose object oriented modular structured simulation testbed [8]. Using this simulation tool, performance parameters can be obtained for the networks with hierarchical traffic routing and the traffic properties of exchanges can be analyzed.

IV. Topological Optimization and Circuit Routing

A. Basic Network Model

There are different models applied in the different phases of PLANET. Here, only the common principles of these models are summarized.

For the present application of PLANET, the telecommunication network is modeled by a simple undirected graph where only one edge exists between every node pair.

The edges of the graph correspond to the links of the network. Four elements of the cost model are taken into account for each edge (see [3]–[5]): the fix, the length-dependent, the capacity-dependent and the cost- and capacity-dependent components of the cost function. Both the length and the capacity dependencies are calculated in linear manner.

The nodes of the graph correspond to the transmission demand endpoints (more than one is allowed on one site), the connection points (the demand endpoints are connected to the network via these points), and the topological points.

The demand endpoints represent the terminals of the different kinds of services.

The connection points play a multiple role in the network modeling since they:

- generalize the simple graph assumption since, in this manner, the optical and microwave links can be modeled between any given node pair,
- make possible to share the costs associated with the nodes and links in the topological optimization phase and so the planner can investigate different cost-rates between the optical and the microwave transmissions,
- provide opportunity to model the different multiplexing and demultiplexing levels at the different nodes in the grouping step.

The application of connection points in the modeling of nodes and links in PLANET is depicted in Fig. 2, where node 1 represents a demand termination point with its optical and microwave connection points, and node 2 shows the role of a topological point. The placements of multiplex and line terminating equipment demonstrate the allowable grouping condition, where the higher level transitions can eliminate the unnecessary equipment.

The topological points represent the cross-points of links where no demand termination and no transmission equipment exist.

B. Topological Optimization

The objective of the topological planning phase within the whole planning process is to find the cost-optimal structure of the network fulfilling the circuit demand requirements and taking into account the technological opportunities as well as the technical (reliability, etc.) and geographical constraints.

The implemented method is based on Minoux's edge elimination technique [3], [4], in which different cost parameters are taken into consideration. For this purpose, there is no meaning of the distinction of the different demand termination points in one site so these points are merged into a single one with combined demand.

The topological planning phase implemented in PLANET can be divided into steps, namely:

- the initial graph generation,
- the preprocessing of the graph considering unirouting requirements, i.e., only one route is required between two demand termination points,
- the optimization core with unirouting,
- the postoptimization of the above result,
- the addition of edges in order to fulfill multirouting requirements.

In principle, the preprocessing algorithm starts from a complete graph. In practice, the significant part of edges are missing from the graph because of the topological and the technical constraints. The method of generation of the initial graph is based on the partition of the nodes into subsets, which handles the topological and the technological conditions, e.g., the latter means that the optical and microwave connection and topological points can be connected only to the other points of the same type.

All subgraphs defined by the given subset of nodes form a complete subgraph generated automatically by PLANET. The connection among the subgraphs can be obtained by defining nodes belonging to more than one subset, by the automatic introduction of edges in a given site (among the demand endpoints and the connection nodes), and there are manual opportunities for the addition or removal of edges between any node pairs, as well.

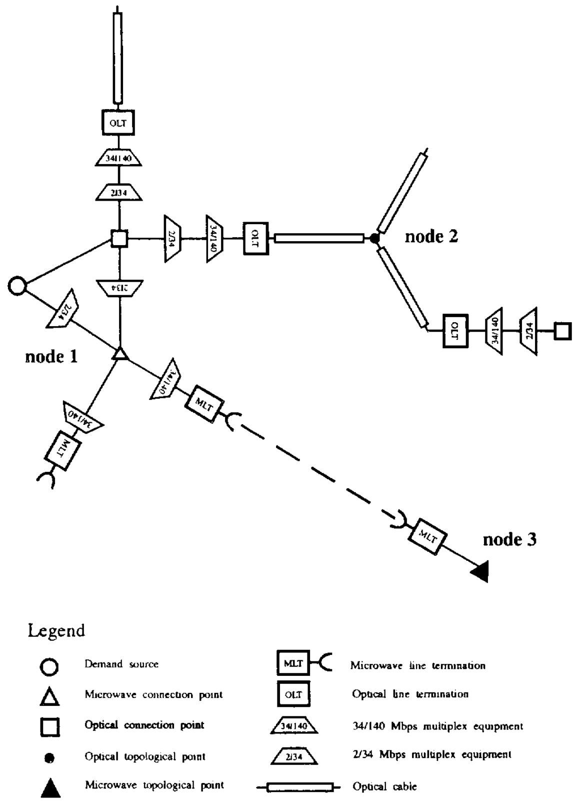

Fig. 2. Node end edge modeling with PLANET.

Using this technique, the generation of the initial graph is very flexible, every topological and technical aspect can be handled, and the number of edges can be significantly reduced.

In order to find the cost-optimal solution, the elimination of the edges from the initial graph is performed by three algorithms, namely the preprocessing, the optimization, and the post-optimization. In the implemented version the routing rule for all of them is unirouting.

In the preprocessing step, the less economical edges are eliminated from the initial graph using a simple and quick heuristic method. The saving is calculated individually for each edge from the estimated maximum capacity in a supposed optimal solution and from the cost of the shortest roundabout route of the given edge (see [3]).

The optimization core is a step-by-step edge elimination algorithm based on a one-level deep, greedy implementation of a branch and bound solution [3]. The lower bound of the saving is calculated for each edge supposing that it is removed. The edge for which the saving is maximum is eliminated and the new routes are determined after every elimination. The procedure stops when the maximum of the lower bounds is not positive or the demands cannot be routed. At the successive steps, the number of investigated edges and the number of calculated rooted minimal trees are reduced by using the previous information (saving, changing of demands realized on the edge).

The post-optimization is similar to the optimization core, but it is based on the exact calculation of saving after the removal of every edge. The gain in cost is usually not too significant, but the number of edges can be a little decreased. This step can also be speeded up by taking into account the previous information about the edges to be investigated.

The three optimization steps can be compared from two points of view. Considering the speed of the algorithms, the basic element is the generation of rooted minimal trees. This step must be performed only once in the whole preprocessing step in order to determine the unirouting of demands: once after every edge removal in the optimization core in order to update the minimal routing and once for each edge in every elimination cycle in the post-optimization step in order to determine the impact of the investigated edge on the network cost.

The other aspect of evaluating of the steps can be defined as the removing effect of them. The experiences for both the Hungarian backbone and Budapest networks were similar, since in order to obtain useful results, the initial graphs were generated with about ten times more edges than the supposed resulting one, the parameters of the preprocessing step were defined to make possible the elimination of about 70% of the edges, the optimization core reduced the number of edges with about 20% and the post-optimization can drop out about 1% of the original number of edges.

After finding the (sub)optimal graph with unirouting assumption, the further objective of topological planning is to increase the connectivity of the graph in order to fulfill the safety requirements. The usual safety techniques (diversed routing, standby network) need at least double connectivity for the demand termination points.

Since the extension of the topology optimization for multirouting increased the running time very significantly, and usually the quite trivial introduction of few edges could result in a graph of high enough connectivity, in PLANET, an interactive method has been implemented. The applied method allows the user to check the fulfillment of the defined connectivity for all node pairs and to add and delete edges with graphical user interface where it is necessary. The graphical interface can be applied during the whole planning process in order to display the actual resulting graph, as well.

C. Routing

After the determination of the network topology, the optimal routing of circuits is derived according to the routing rules associated to the connection points of every pair of demand endpoints.

The routing rules define the number of necessary edge or node disjoint paths, as well as the sharing of the demand among the paths.

In the recent version of PLANET, there can be different routing rules for the demands of different services and the

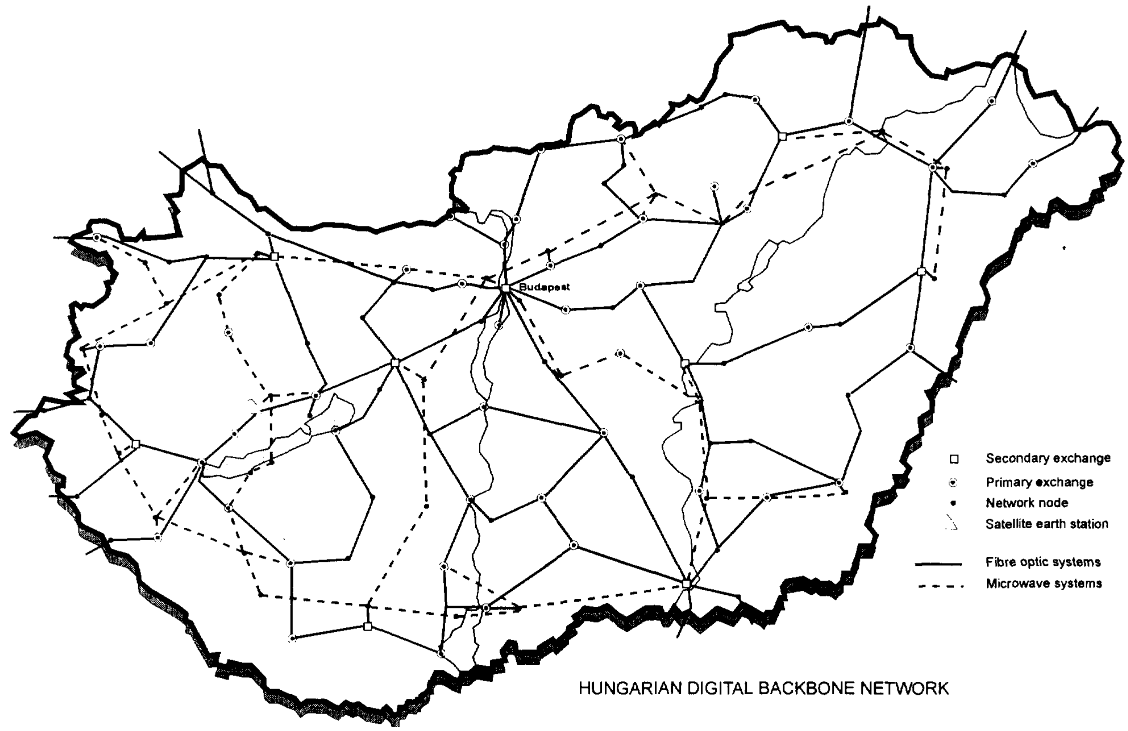

Fig. 3. The graphical result of the topological planning.

user can also introduce special requirements for the individual demands. The minimal uniroutes or multiroutes are determined without edge capacity constraints, but there are also further opportunities for the interactive modification of the previously obtained routes. The results of the topological planning are demonstrated in Fig. 3.

V. Grouping and Assignment

The results of the optimization of the network structure and the routing of circuit demands are fixed for a longer period and this planning phase is followed by the more detailed description of the shorter time network plan.

A. Grouping

The first step of the detailed transmission planning phase is the grouping of circuit demands. The objective of this step is defined as the determination of the optimal multiplexing and demultiplexing solution of circuit demands at the nodes of the network.

The optimum of grouping can be identified in some cases in the total cost of the network, the total cost of the transmission systems, and the reliability of the routing via the transmission systems.

The input of grouping is the given routing of circuits via the links of the network. The routing which was determined in the topological planning phase is fixed during this planning step.

The demands of different services can be handled in different units corresponding to the hierarchy of the module levels of the transmission systems.

The multiplexing capabilities are given for each node in the form of the allowed minimum and maximum module level. The introduction of connection points in the demand termination sites can be utilized very efficiently in this phase since these additional points make possible to model the multiplexing–demultiplexing activities partly associated with the links (between two connection points) or partly associated with the nodes (between a connection point and a demand endpoint or between the two—optical and microwave—connection points of the given node).

Considering the circuit demands and the possible node module levels, the grouping optimization is carried out from the lowest to the highest module level, eg., from the first to the fourth module level in PDH networks, subsequently. In every level there are different opening and closing thresholds of a module.

Two basic approaches are used for the heuristic optimization of circuit grouping. The first one is formed for the fast and simple solution of this task. In this case, only two possible forms of realization can be generated for a given circuit demand:

- if the demands between a node pair are greater than the opening threshold of the given module level, the demands are grouped together and are routed between the two nodes without demultiplexing (end-to-end grouping),

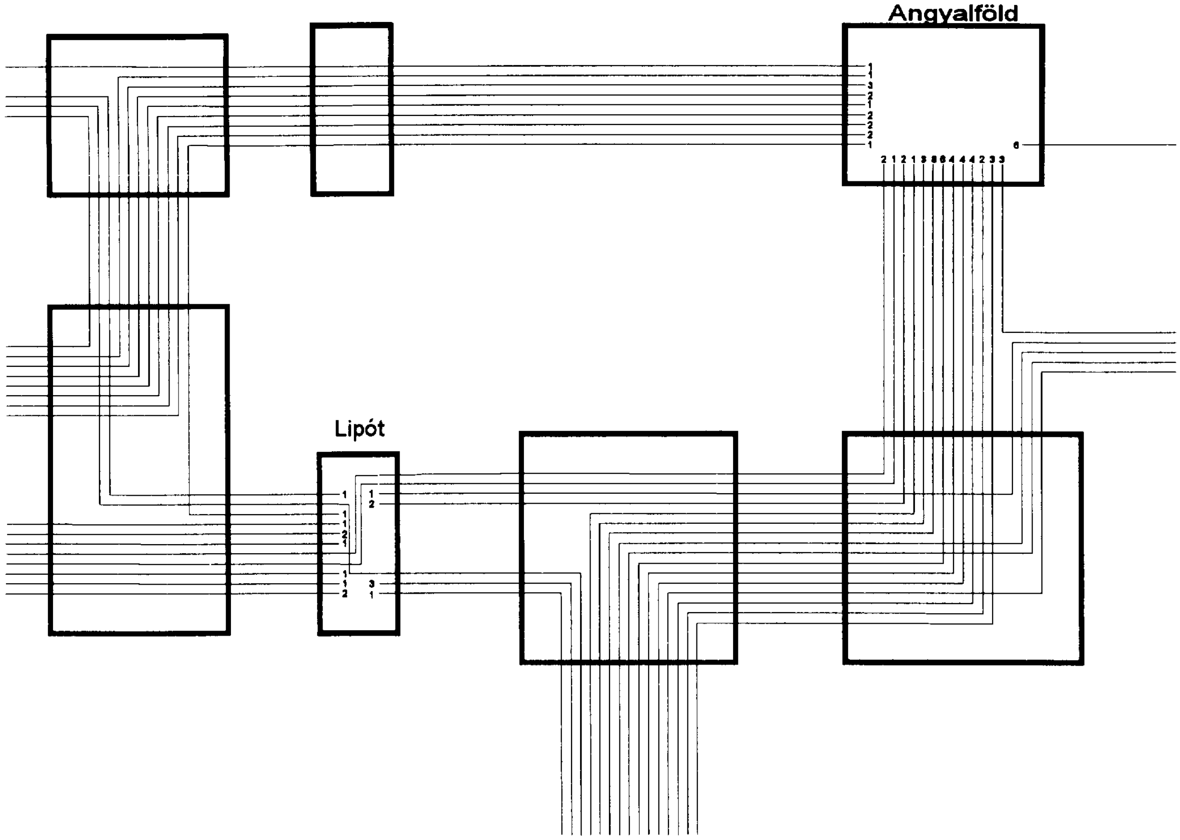

Fig. 4. The graphical result of the grouping step.

- if the demands are not great enough, they are demultiplexed and multiplexed in every node between the two terminals where the minimum module level allows the demultiplexing (section-by-section grouping).

The other solution is a more complicated free optimization of the grouping. In this case, the handling of great demands starts similarly to the former one. However, if the demand is not great enough, then the optimization of inserting a single multiplexing-demultiplexing point is initialized taking into account the realizing possibilities. In this case, at every module level the longer demands are investigated first. The optimal point is decided by the length in term of sections, by the size of the bundle or both, by the minimal module level of the nodes between the two terminals, or by other priority rules. This procedure is rather time consuming but the amount of multiplex equipment can be significantly decreased in networks of real size.

In both grouping versions, there is a further opportunity in PLANET for a post-optimization step to eliminate the unnecessary demultiplexing and multiplexing points of demands.

As a result of this optimization, module routes are generated at every level. The graphical documentation of the highest level relations is one of the interesting features of PLANET as it is demonstrated in Fig. 4. In the figure, the boxes represent the nodes of the network where the connection points and the demand termination points of a given node are merged into a single box. The lines ending in a box correspond to the unmultiplexed fourth level bundles while the lines crossing the boxes describe the crossconnected systems.

The speciality of the documentation is the semiautomatic generation of this figure based on the grouping results. The only manual activity required from the user is the modification of the placement of the boxes in order to improve the view of the AutoCad figure.

B. Equipment Assignment

The objective of the assignment step is to define the detailed payload of each equipment. Each demand can enter a transmission system at the demand unit, e.g., 2, 8, 34, or 140 Mbps. In the recent version of PLANET, the assignment is determined with the constraints of the grouping solution, but there are possibilities for finding other solutions, eg., considering reliability aspects. In the latter case, the number of equipment can increase and the

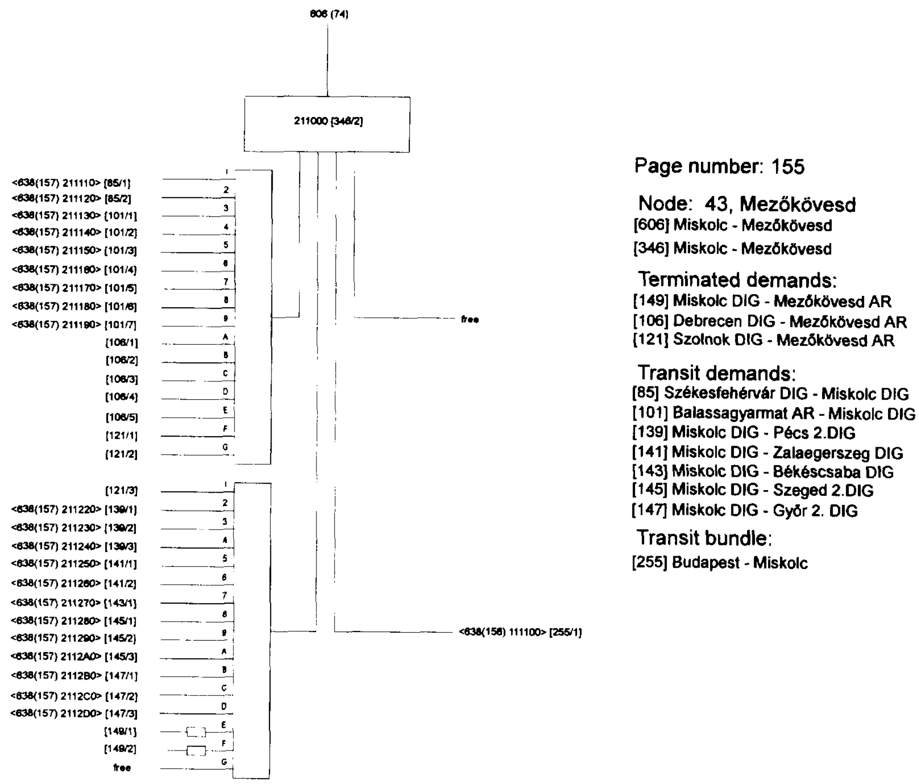

Fig. 5. The graphical result of the equipment assignment step.

result can be considered as a refined network dimensioning.

In this step, the demand assignment, the cross-connect functions, and the graphical documentation are determined. The result of this planning phase is demonstrated in Fig. 5, where the terminal and transit demands of a given equipment can be realized on the different module levels.

VI. Planning Processes

As it was mentioned in the previous sections, three main planning activities considering the perspective of planning can be distinguished, namely:

- long-term planning,
- medium-term planning,
- short-term planning.

In the following, these three planning processes are discussed in detail. The main objectives, the input data, the planning activities, and the planning results to be obtained are summarized, respectively.

A. Long-Term Planning with PLANET

The aim of the long-term planning process is to determine the optimal network structure. The usual role of the long-term planning in the whole planning process is identified as the choice of a target network for the end of a technological development period.

An important consequence derived from the objective of this planning process is the uncertainty of the input data since for a longer period both the service demands as well as the technological and cost parameters of network development can be foreseen only very roughly. Thus in practice, the real aim of the long-term planning can never be the construction of a cost-optimal network, but it must assist in studying a great number of development scenarios and obtaining as flexible a target network structure as possible.

The input data needed by long-term planning are the nodes (demand endpoints, topological points), the technical and geographical constrains facing the formation of topology, the traffic demand versions of different kinds of services, the safety requirements, and the technical and cost characteristics of potential equipment.

The steps that must be carried out are determined by the objectives and the possibilities, i.e., these planning steps are basically focused on the topological optimization. The elements of the long-term planning process are shown in Fig. 6. The first two blocks cover the topological optimization steps described in Section IV. In the third block, the simplest version of grouping is applied in order to obtain approximate equipment combinations and costs, while the fourth one is established for the evaluation and

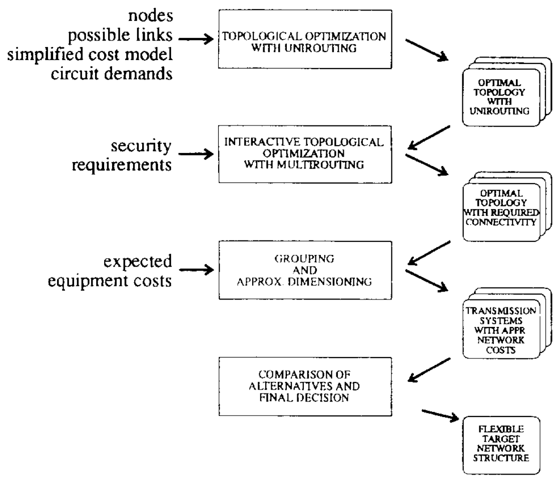

Fig. 6. The elements of the long term planning process.

comparison of the plan versions from some points of view, e.g., cost, reliability, robustness, flexibility, etc.

The results of the long-term planning basically appear in the form of the topology of the flexible target network with approximate edge capacities and with the main equipment allocation solution. Naturally, the target network can never be considered as an existing future network to be realized at the given planning date; its basic function is the structural orientation for the shorter time developments.

The elements of PLANET provide efficient support in the long-term planning. The database and the planbase help the user to build up different visions of the network while the planning and the analysis parts assist the topological optimization, the simplified grouping method makes possible the determination of the approximate cost of the target network, where the results can be mainly used for the comparison of different alternatives and not for the determination of the real amount of the necessary investment.

B. Medium-Term Planning with PLANET

The medium-term planning is subject to the determination of plans for maximum 5 years. For this period, existing and new service demands, technological possibilities, and constraints, as well as financial (state and/or company) possibilities are quite well known, and differing from the target network planning, the impact of the existing network on the possible solution is very significant.

The medium-term planning process needs demands, safety requirements for the planning period, technical and cost data of equipment to be implemented, target network structure from the long-term planning, and detailed description of the existing network (a result of an appropriate short-term planning), as input data.

The PLANET-based medium-term planning process is carried out in two ways. If the medium-term period is the first one of a new long-term period introducing new technology, the existing network is considered as the realized demands and the links with the actual transmission capacities only. In this case, an overlay network is determined, (e.g., SDH introduction). The planning process must handle the development of a parallel network but since it is at a beginning phase, the new network can be planned similarly to the long-term planning process. However, having the target network, the medium-term planning process differs from the long-term one because in this case the emphasis is put on the determination of edges to be realized in the medium-term period, as well as on the detailed solution of routing, grouping, and equipment assignment instead of the network optimization.

If there is no change in the technology within a given medium-term planning period, the existing network will additionally describe the grouping (and implicitly the routing), as well. (This has been the situation in the digital PDH network development lately.) In this case, the effective planning phase is preceded by a preprocessing step in which the existing network topology can be supplemented with new links taking into consideration the target network architecture in order to connect new demand endpoints or improve the connectivity (if needed). The procedure according to which the medium-term planning is realized in the second case is depicted in Fig. 7.

The circuit demands for the planning period are determined by the traffic planning process and the usual task of the medium-term planning in this case is to realize the increase of demands. Sometimes the evolution of the existing network towards the target one needs the modification of existing demand realizations. These demands should be rerouted with the new demands according to the new requirements.

The routing process of medium-term planning is based on the routing module of PLANET (described in Section IV-C), but it takes into account the existing free transmission capacities of the links. In case of saturation (when the free capacity is less than the demand to be routed), investments are allowed (with increased linear cost) or the saturated edge can be excluded from the further routing, optionally. At the end of this planning process, the solutions of grouping are also carried out. The grouping process is based on the grouping module of PLANET, but takes into account the existing multiplex structure and tries to fill the existing free bundles before opening a new one. The equipment assignment is processed in order to refine network dimensioning and determine the approximate network cost.

The final decisions in the medium-term planning are based on the evaluation and comparisons of different planning alternatives. The result describes the optimal evolution of the network, the implementation of new edges, equipment, demands, and the modification of the realization and utilization of the existing demands and equipment.

C. Short-Term Planning with PLANET

The short-term planning is the preparation of the investments for the near future taking into account the ac-

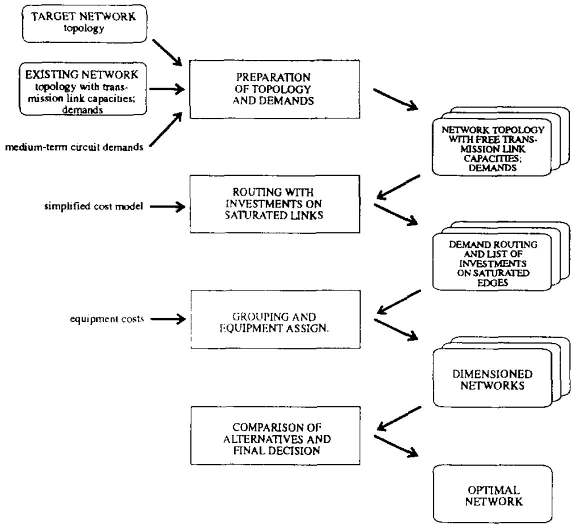

Fig. 7. The elements of the medium term planning process.

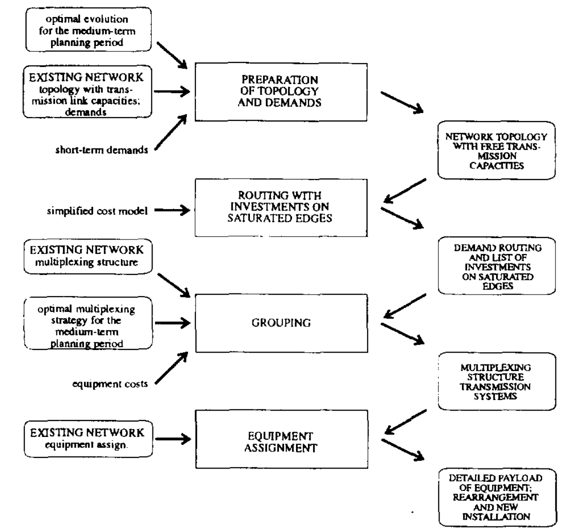

Fig. 8. The elements of the short term planning process.

tual financial and technological constraints. As far as the long-term and the medium-term planning steps optimize the network from different aspects, the short-term planning only gives the dimensions of the network and provides huge and detailed documentation for the installation. A series of the short-term plans is a year-by-year decomposition of an optimal medium-term plan. The elements of the short-term planning process are shown in Fig. 8.

The input data of the short-term planning include demands for the planning year, cost and equipment data, the detailed description of the existing network (demands, capacities, detailed equipment assignment), the evolution, and multiplexing policy according to the optimal medium-term plan.

The planning parameters for the grouping originate from the grouping policy optimized in the medium-term planning. At the end of the short-term planning, the detailed payload of each equipment is determined with the help of the equipment assignment module of PLANET.

VII. Applications of PLANET

As it was mentioned, the development of PLANET was started in 1989. Since 1991, it has been used in PKI–TDI and it has been continuously developed. At the moment, the PLANET system consists of more than 27 Mbytes of 200 executable programs and about 10 Mbytes of more than 800 Pascal, C, and Assembler source files.

The applications of PLANET cover a wide range of planning activities at PKI–TDI. Here only the most important examples are summarized.

A. Hungarian Digital Backbone Network

During the last few years PLANET has been applied many times in the planning of the digital backbone network. Long-term plans for 2000, medium-term plans for 1996, and short-term plans for 1993, 1994 have been developed together with about 50 versions.

The topological optimization, the node-disjoint multi-routing, the two basic grouping policies, and the equipment assignment method as well as the automatic documentation tools have been applied.

The network consists of 56 switching nodes (9 secondary and 47 primary points), and about 100 optical and microwave links. The results are illustrated in Fig. 3 and 5, where the long-term network topology and the short term equipment assignment are depicted.

B. Budapest Trunk Network

There have been similar investigations relating to the Budapest network development. The investigated networks can be characterized by 27 exchanges and about 50 further topological points, with about 120 optical and microwave links. The defined node models help the planners to study different grouping versions. Long term plans for 2000 and medium-term plans for 1994–96 have been obtained with about 20 plan versions.

The investigations resulted in the digital target topology, as well as the routing and grouping solutions. Up to now, the equipment assignment method was not applied for the Budapest trunk network. The target network topology and a part of the medium term grouping solution are demonstrated in Figs. 9 and 4.

Besides the transmission plans, a detailed traffic simulation study of the Budapest network has been also carried out. The network includes (logically one, physically two) tandem, interurban, and international exchanges with hierarchical alternate routing from the point of view of traffic.

The question for the traffic simulation has been established as the study of very intensive development from 20

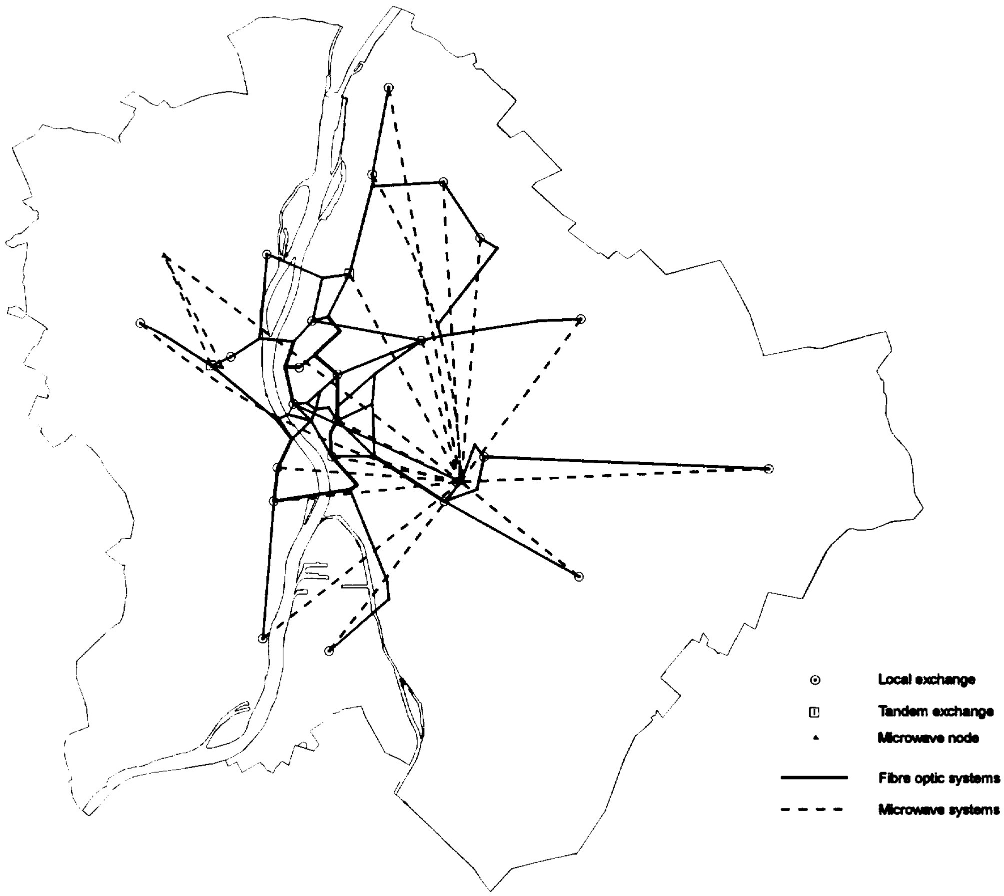

Fig. 9. Long-term Budapest topology.

to 40 switching exchanges where digital ones with full accessibility and crossbar ones (ARF 102) with limited accessibility exist, and they have to be taken into consideration in the near future, too. The integrated simulation tools have provided possibility to verify the traffic plans in two levels [9]:

- simulation of outgoing traffic of ARF 102 switching center,
- traffic simulation of network with hierarchical, alternate routing.

Using this element of PLANET, users have been able to obtain results not only for the network level, but for evaluation of the effect of the grading in the crossbar exchanges in real network environment, as well.

VIII. Ongoing Developments—SDH Network Planning

As it was mentioned PLANET forms not only a closed software tool for the actual network planning activities but it means a frame for future developments, as well. The major part of the ongoing developments concerns the synchronous digital hierarchy (SDH) network planning.

New blocks of PLANET are being developed to help planning and dimensioning add-drop multiplexer (ADM) based self-healing rings (on equipment level). The module includes two-dimensioning methods. A draft one is based on the circuit routing on different kinds of self-healing rings (unidirectional, bidirectional), and an integrated routing-grouping process for detailed dimensioning. This process can provide detailed payload of ADM ports processing the equipment assignment, optionally.

The implemented routing and grouping modules of PLANET can be applied for planning of digital cross-connect (DXC) based meshed networks without major modifications. A new block is under development for standby network planning, DXC dimensioning, and equipment assignment will complete the planning tools aiming at DXC based meshed networks.

The new modules are developed and implemented according to two new planning processes. An SDH target network optimization process can be established with the help of a hierarchical SDH network description, where graphical user interface and the basic SDH network structure dimensioning methods can be applied. Due to the complexity of the problem no direct structure optimiza-

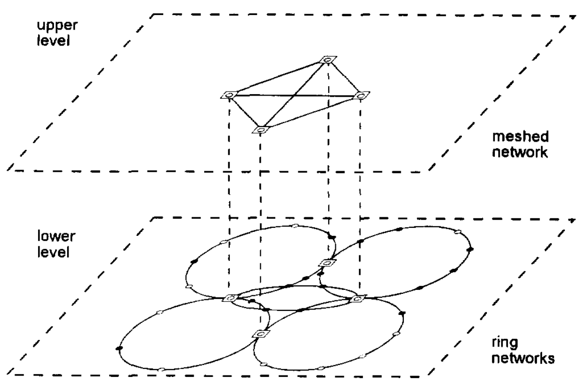

Fig. 10. A possible architecture of the Budapest SDH network.

tion is implemented, only the evaluation and comparison of user defined structures are planned to be available.

A mixed PDH-SDH (PDH: plesiochronous digital hierarchy) network planning process is also being implemented to evaluate introduction strategies. This planning process combines the elements SDH target network evaluation and the PDH medium-term planning processes.

Some basic SDH planning methods were implemented in 1992, and have been applied in the investigation of the SDH target network architecture and mixed PDH-SDH network planning in Budapest. The investigated network can be characterized with 41 exchanges on 30 sites with two tandem, interurban, and international exchanges. In the successful application, several network structures were evaluated in a wide range of circuit demands from 4450 to 11167 2 Mbps units. Taking into consideration technical, economical and evolutional aspects a two-level hierarchical network structure was found as an optimum (see Fig. 10). There are five ADM based rings with dual homing on the lower level, (four nodes in two different rings without DXC capabilities for ring capacity reasons) and a DXC based full mesh with four nodes on the higher level. The experiences of the application have provided useful information of how the SDH network planning modules and processes can be improved this year. The integration of the SDH planning modules and processes into the PLANET frame is in progress.

IX. Conclusions

PLANET is a software tool for the computer-aided planning of telecommunication networks, and it is introduced in the everyday planning activity of the PKI Telecommunication Development Institute of Hungarian Telecom Company.

Up to now, the application of PLANET has been forced to use a more precise model generation than the earlier manual solutions, and PLANET assists the user in obtaining a couple of results within a very short time (hours) after modeling a new problem.

However, PLANET can be considered not only as an existing planning tool, but as a frame for the realization of new planning phases and methods, as well. Some further blocks under preparation are as follows:

- network reliability analysis (RELNET),
- SDH network planning,
- traffic analysis and network simulation with nonhierarchical traffic routing.

Finally, it can be mentioned that the implementation of PLANET on workstations has been also prepared in order to build up a more powerful tool for the actual planning problems with more precise models and for the new planning issues, as well.

Acknowledgment

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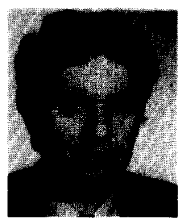

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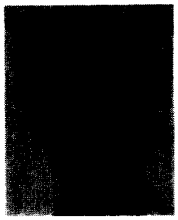

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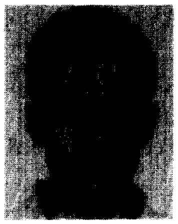

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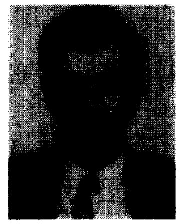

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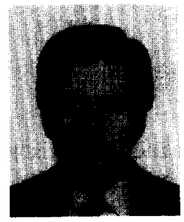

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