IMMuNe
Integrated Management for Multimedia Networks
A proposal to the
Swiss National Science Foundation
in response to the Priority Programme
for Information and Communication Structures
(SPP ICS)
by

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2 Scientific Part

2.1 Overview of Research Plan

The project will develop a new direction for managing multimedia networks, that is based on the vertical integration of short, middle and long term aspects. Networks such as the Internet, which have an organic structure without explicit resource allocation, offer very poor service guarantees. In order to achieve the high reliability requirements required of multimedia networks, it is necessary to explicitly allocate resources in a way which avoids overloading. This resource allocation problem is combinatorial and thus carries an exponential computational complexity, yet it has to be solved in real-time. These contradictory requirements can only reconciled by planning. The demands for communication between particular points of the network must be predicted in high level abstractions, such as numbers of users and service profiles per user. The service provider can then determine demand forecasts and plan networks and their usage in order to provide the capacity required. By making this information available to the communication nodes, their problem looses its combinatorial complexity and can be solved efficiently. In this project, we consider networks that provide multimedia information services (Multimedia Information Services Networks). They will be based on Integrated Services Internet protocols (IP and RSVP) carried by ATM networks: routers supporting IP and/or resource reservation (RSVP) are interconnected by ATM connections.
The resource allocation problem poses itself at three different levels:

1. short-term decisions about routing and connection acceptance which are made by network elements in a distributed fashion,

2. network management by operators who set network parameters to optimize performance, and resources,

3. long-term planning of network topology and allocation strategies.

In current technologies, the three different levels are separated. Thus, the resource allocation scheme cannot take into account the foresight of the network planner, and the planner's misconceptions about traffic patterns and routing are not pointed out.
In this project, we will consider the vertical integration of the different levels through collaboration of specialists in each area. At the level of resource allocation, we will develop routing schemes which are implementable on IP and RSVP over ATM networks. At the level of network management, we will develop supervision and distribution schemes which can adjust routing schemes to the current traffic situation. At the level of planning, we will develop a planning tool using abstractions defined on the schemes of the lower levels which is capable of translating the intentions of the planner into suitable allocation schemes. This integrated solution will show a new direction for solving the network management issues associated with the multimedia information highway.

Keywords: resource allocation, routing, network management, vertical integration, ATM, IP, RSVP.

2.2 Research plan

2.2.1 State of the art

Most applications of Artificial Intelligence in communication networks have focused on the problems of fault diagnosis and fault management. Large networks such as the SWIFT network for interbank communication have long had expert systems to assist in their management. The most recent overview of applications of knowledge systems in telecommunications networks can be found in [1].
Resource allocation has been recognized as a problem more recently. The importance of resource allocation for network performance, resource utilization and its impact on the profitability (of the service provider), and the significance for the network users is discussed in [2]. The first specific work on heuristic methods is described by Efe in [3]. Boutaba, Folliot and Sens [4] describe an allocation strategy based on local heuristics, such as "assign the longest processes first". Franken and Haverkort [5] have worked on a performance manager which proposes network reconfigurations to improve performance. Here, the program searches for new configurations at run time, and in large networks may fail to find a good solution in time. [6] discusses an expert system called ANMA under development for ATM networks. It addresses fault diagnosis and management, but also includes modules for collecting performance information and suggesting changes to routing tables and network topology to improve performance. ANMA is the only tool which implements a connection between network planning and routing decisions, but it does so in a very rudimentary and ad-hoc fashion.
Another aspect of resource allocation problem is to find architectural solutions that can improve the performance of connection handling. Broadband networks design and control, given their connection oriented nature for supporting real time traffic, have additional complexity compared to traditional networks. This complexity is mainly required to support connections. Every connection established through the network is associated at every node with label swapping tables, with capacity reserved in queues, and with connection control blocks (or equivalent denominations) used by the signaling or control protocol; connection establishment, tear-down, or simply keep-alive requires some processing [7]. Gün and Guérin [7] define a complete framework for minimizing the bandwidth associated to each connection, considering system parameters and statistical multiplexing in computing the bandwidth necessary to the connection. This solution, though offers a complete architectural solution to the resource allocation problem, is based on some assumptions that do not reflect the behavior of real networks. Every connection is also influenced by the call processing delay, propagation delay, the admission control function (due to QOS requirements) and routing algorithm at every node [8]. Due to these points, algorithm based on pre-computation have been proposed [9] [10]. Path pre-computation is possible, though more complex, but with the advantage of reducing connection setup latency and cost, and the possibility to reuse the same pre-computed path for several connections. Compared to traditional networks, broadband networks require complex, distributed real time monitoring, control and management capabilities in order to guarantee the QOS for communication services they integrate [11] [12]. In [12], a framework is given for allocating resources to virtual paths, and letting virtual path connections allocate resources to individ-

ual connections. The key issue is the distribution of physical link resources to VPs. The model applies to cases where connections belong to a discrete set of classes. The architectural solution proposed in [12] is more general and introduces the key concept of VP to group connections, but it offers only a group of indications in the direction of solving the resource allocation problem.

2.2.2 Consortium Research:

EPFL/LIA work

In previous ESPRIT (EQUATOR) and SPP projects, Berthe Choueiry of the LIA has developed a novel concept for resource allocation based on a hierarchy of abstractions [13], [14], [15]. In this approach, known techniques of operations research, such as list coloring heuristics, are cast in a different framework. Rather than being used to compute a single solution to a particular problem, they serve only to group similar tasks into larger units. This simplifies the problem so that it becomes easier to solve by computer or even by a human operator. The approach can be applied directly to certain telecommunications problems [16]. In an ongoing project, we are further generalizing it to find abstractions of the graph structures present in networks.

EPFL/TCOM work:

One of the main research areas of the Telecommunications Laboratory (TCOM) is in the area of service engineering. Our research project aims at developing an open service architecture based on Intelligent Network (IN) and Telecommunication Management Network (TMN) architectures and Open Distributed Processing (ODP). We already have a considerable know-how in IN with the development of an IN platform within a project with the Swiss TELECOM PTT (FE 242). Tools for IN service specification and validation have been developed [17]. Following a contract with Digital Corporation Inc., this work is now ported to the DEC-Alpha environment to be run in operational networks. Concerning TMN, we have participated in the RACE II projects PRISM that is related to service management with a focus on Virtual Private Network management [18] and BETEUS concerned partly with ATM network management [19]. Within the WEB over ATM project funded by the Swiss Federal Institute of Technology, we are currently realizing a management architecture for the management of multimedia services run by the WEB, the management of the hosts running the WEB, and the management of broadband network resources together. Furthermore, the integration of these management levels is studied.
Internally, we are currently developing OAMS (Open Management Architecture for Multimedia Services over ATM) over DCE (Distributed Computing Environment). OAMS objectives are similar to those of TINA or ROSA, but OAMS is built on different concepts [20]. An emphasis has been put on connection management [21]. We are currently adding new functionalities to this architecture such as fault and configuration management and the introduction of delegated agents.

EPFL/LRC work:

Research at Laboratoire de Reseaux de Communication (LRC) focuses on the internal mechanism of communication networks. The SCONE project (Scalability Enhancements for Connection Oriented Networks) aims at developing an architecture for reducing connection cost [22],[23],[24]. It applies to two scenario: ATM case, and RSVP ov er ATM case. SCONE relies on a small set of design guidelines:

- group point to point connection using virtual trunks,
- open group support for multipoint connections,
- virtual trunks are edge to edge.

SCONE consider the use of route pre-computation [25],[26]. This project is funded by EPFL and ACTS EXPERT project. LRC has put in place, inside EPFL, the Web over ATM project. The goal of the project is to make the benefits of ATM quality available to end users in a Web environment. Challenges are to bring the necessary performance improvements to Web infrastructure, combine the IP suite with end to end ATM, experiment with virtual reality applications , understand the quality of service really needed by video applications , and manage the whole [27]. Another area researched in LRC is performance of ATM networks. One issue is that modeling should take into account the closed loop due to transport protocols [28],[29],[30],[31]. Taking a snapshot of traffic on one network and using the result as a source model in another network fails to capture this effect. We have applied this idea to the dimensioning of an DQDB / ATM interworking unit; we compared results obtained with (a) a model based on off-line measurements and (b) an active model representing the effect of TCP. The conclusion is that a significant difference exists, model (a) being too pessimistic. This was confirmed by measurements on the COMBINE testbed. We measured Ethernet traces at EPFL. We are applying the measurements and this research to the evaluation of a connection-less service and of the ABR service in a public network context. This project is funded by two Swiss TELECOM grants; until March 1995, it was also supported by OFES (RACE project COMBINE).

Swiss TELECOM PTT work:

The mission of FE (the Swiss TELECOM PTT research and development laboratory) is to develop competitive advantages by innovation. FE in cooperation with its UNISOURCE partners, or on its own, is able to develop (key components of) planning tools, like proposed in the IMMuNe project. Such tools potentially provide large improvements, and permit to Swiss TELECOM PTT to compete with the other UNISOURCE research and development laboratories from other countries. The Swiss TELECOM PTT research and development laboratory is developing various tools (in collaboration with universities) for network design, in particular enterprise network design [32],[33]. Recently, tools for designing ATM-based virtual private networks are studied and developed. The key factors for the success of such tools in the real world are cooperative problem solving and the ability of the user to take responsibility [34]. Therefore,

work is under way for improving this aspect of our planning tools [35].
The Swiss TELECOM PTT is also participating in the SPP/ACTRIS project proposal Computer Aided Network Planning Cockpit (CAN PC), that is compelementary to this proposal, because its focous is the integration of existing network planing capabilities into a single extensible framework. Naturally, Swiss TELECOM PTT plans to accomplish more (and develop a more extensive framework) by sharing software components that are reuseable.
A component-oriented formal representation of software function for design and network management tasks (e.g., diagnosis and configuration) is under development [36],[37]. This framework provides mechanism for correctly and efficiently combining (independently developed) functional components.

ETHZ/TIK work:

The computer Engineering and Networks Laboratory (TIK) is presently engaged in three advanced multimedia and CSCW research projects:

- In the context of the RACE/CIO research project, the communications system research group has developed (in cooperation with international partners) the so-called JVTOS application sharing system. JVTOS stands for Joint Viewing and Teleoperation; it allows application sharing through a multiplexing approach. Also, a videophone service has been integrated in JVTOS. Results of this project are presently being exploited in the joint EPFL/ETHZ Telepoly project, aimed at distance learning. For an overview of the JVTOS project, see [38].

- In the ETHMICS project, an experimental multimedia communication platform is being developed, incorporating both hardware (i.e. multimedia workstations and high performance LAN) and software. For an overview of this project, see /citeb72. In contrast to the JVTOS approach just explained, the ETHMICS software architecture is based on distributed object, with the aim of building lean, flexible application packages, and defining a proper QoS architecture [39]. Although developed independently from the MSS approach [40], the ETHMICS architecture bears many similarities. For ATM-oriented networks, an object-oriented framework serving as a distributed kernel operating system, with QoS-determined resource allocation has been developed [41].

- The DaCaPo System [42] is based on three layer model that splits communication systems into the layers A (application oriented), C and T (basic transport infrastructure). Layer C is decomposed into protocol functions instead of sub-layers. C protocols are configures dynamically (i.e. at connection setup), according to QoS requirements, and properties of T.

Considerable know-how has also been acquires in modeling the performance of ATM networks. In the context of the ARES (ATM Real Time Emulation System) project, the impact of different network configurations on QoS is presently being studied. Experience gained in this project may be used in the Network Infrastructure Planning subproject (B).

2.2.3 Detailed research plan

Note: even though this proposal is for the initial two-year period, we outline a research plan for the full four-year duration of the project.
Management of resources in networks involves processes at three different levels, as presented in figure 1:

- short-term, distributed in the network: monitoring traffic, accepting-rejecting connection of flow requests, and routing connections or packets
- medium-term, by operators: determining traffic characteristics, deciding acceptance/rejectance policies, deciding routing policies, and optimizing revenue
- long-term, by network planners: planning network topology, dimensioning network elements, and preparing plans for specific traffic patterns

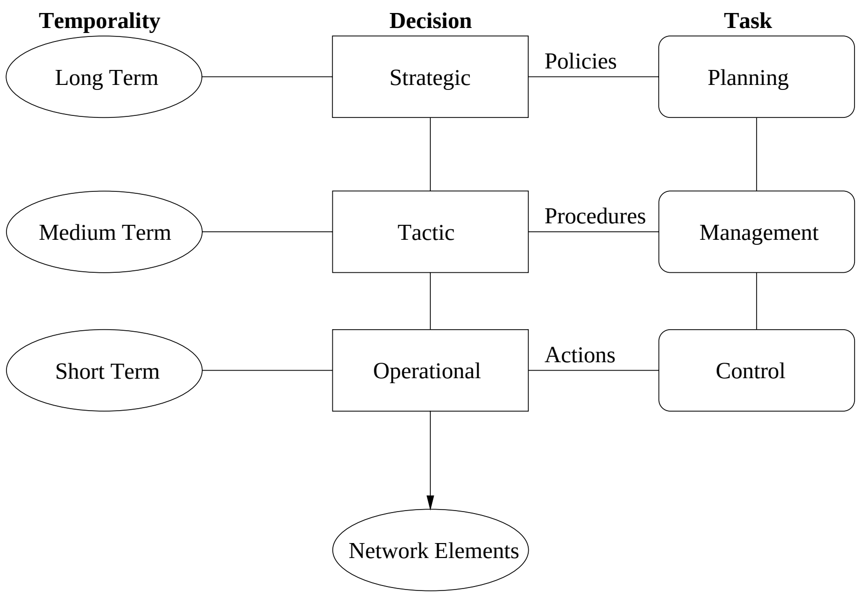

Figure 1: Vertical Integration: three levels architecture.

Interactions exist between all levels, and they share both function and data. Short term mechanisms require and provide data about the actual traffic patterns and how they relate to the high level abstractions. For example, connection acceptance accepts or rejects connections based on an optimization strategy for connection blocking for different types of connections; the optimization strategy uses an objective function which is derived from planning intentions and from the actual network configuration. Key issues are (1) to adapt the resource allocation mechanisms at all levels to the current load and traffic behavior and (2) to pass the planning intentions down to the medium and short term levels. In so doing, it is essential to reduce the complexity of network management, and of the network itself. The model of networks we consider is the Multimedia Information Services Networks Model, i.e networks that provide multimedia information service, based on Integrated Services Internet protocols (IP and RSVP) carried by ATM networks. In our model, routers supporting IP and/or resource reservation (RSVP) are interconnected by ATM connections.

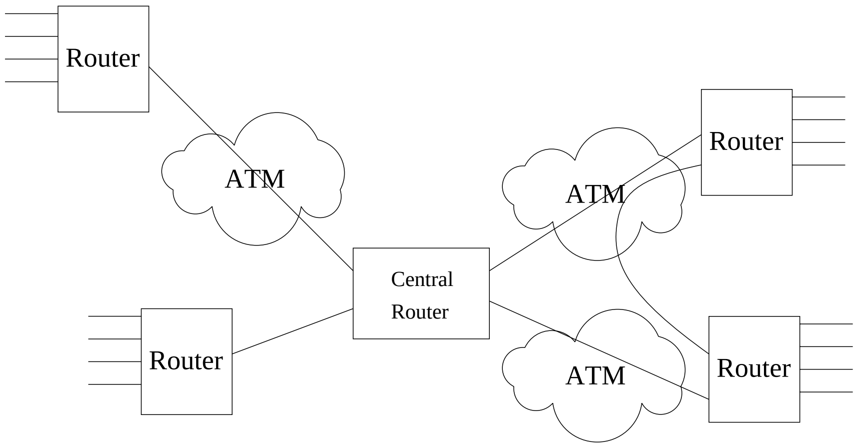

Figure 2: Testbed Network used by IMMuNe

The project will deliver an integrated network management architecture, in form of theoretical results, their implementation on a prototype, and validation on a real integrated service multimedia network. As shown in figure 1, the integrated network management architecture consists of three parts:

- long term management (WP2)
- short and medium term management (WP3)
- network management architecture for vertical integration (WP4).

Validation of the concepts will be performed based on simulation platforms developed in WP2 to 4, and on real life measurements obtained from:

- measurements on real integrated services ATM network (WP5).

In particular, a comparison will be made with ETHMICS scheme [41] for resource allocation, aiming at an integrated solution valid for both LAN and WAN situations.

Work Packages and Tasks effort This paragraph define the duration of each working package and, inside each working package, the duration of each single task. As already specified below, the research plan is for four years. Some task, that is foreseen for the third and for the fourth years, is also included and indicated as future perspective task. For working packages the responsible partner is also indicated.

WP1 **Project Coordination - LRC (48 months)**

WP2 **Planning Tools - LIA (48 months)**

T2.1 Definition of resource and demand models (6 months)

T2.2 Network planning tool (12 months)

T2.3 Definition of possible allocation strategies (6 months)

T2.4 Intelligent Analysis and Simulation tools (9 months - future perspective)

T2.5 Learning traffic patterns (6 months - future perspective)

T2.6 Implementation on a test network (9 months - future perspective)

WP3 **Resource Management in short and medium term - LRC (48 months)**

T3.1 Resource Allocation in the short and medium term (15 months)

T3.2 Traffic Characterization (9 months)

T3.3 Implementation of Short Term resource management for reducing connection handling costs (12 months - future perspective)

T3.4 Platform (12 months - future perspective)

WP4 **Network Management Architecture - TCOM (48 months)**

T4.1 Definition of a management agent oriented language (12 months)

T4.2 Validation of specifications (12 months)

T4.3 Management framework (6 months - future perspective)

T4.4 Application to particular management functions (9 months - future perspective)

T4.5 Study of the interfaces with short term and long term management (9 months - future perspective)

WP5 **Technology Transfer - PTT and TIK (48 months)**

T5.1 Tool and method development (48 months - partially future perspective)

T5.2 Network and Service Management (36 months - partially future perspective)

T5.3 Interaction of Delegated Management Procedures (18 months)

T5.4 Integrated solution for both LAN and WAN (36 months - partially future perspective)

Time plan, milestones and deliverables In figure 3 is reported the time plan, and figure 4 defines the work packages milestones, both for the first two years. The complete list of milestones for four years is given in Section 2.4 at page 4.

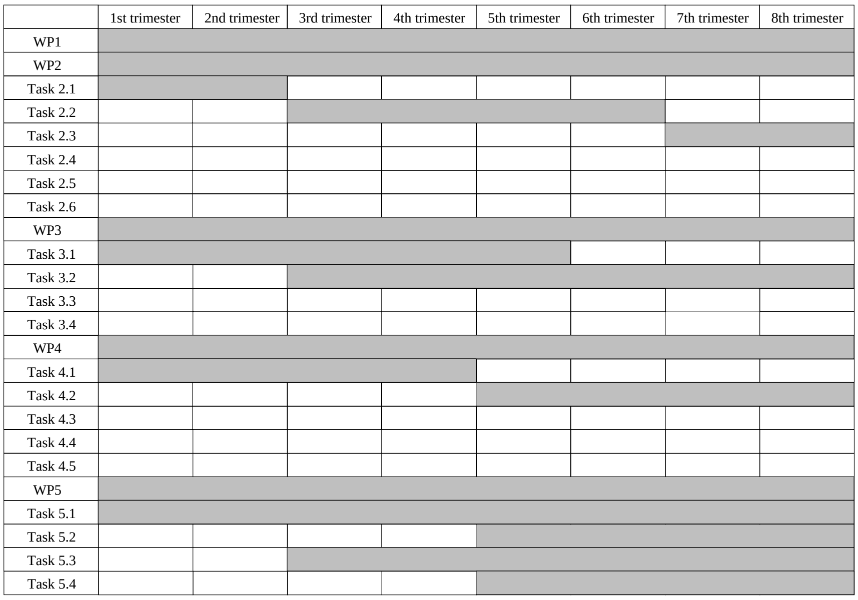

Figure 3: Work Packages and Tasks Time Plan

	1st trimester	2nd trimester	3rd trimester	4th trimester	5th trimester	6th trimester	7th trimester	8th trimester
WP1								
WP2		resource and demand models				network planning tool		allocation strategies
WP3					modelling method			traffic model
WP4				mngm agent oriented lang.				validation
WP5								field traial

Figure 4: Work Packages Milestones

List of Deliverables

Del. N^o and WP	Deliverable Title	Date Due
01 WP4	Management Agent Oriented Language	31 Mar. 97
02 WP3	Modeling Method	30 Jun. 97
03 WP2	Network Planning Tool	30 Sep. 97
04 WP2	Allocation Strategies	31 Mar. 98
05 WP3	Traffic Model	31 Mar. 98
06 WP4	Report on Validation	31 Mar. 98
07 WP5	Final Trial Results	31 Mar. 98

Work Package 1: Project Coordination WP1 will coordinate the concepts and prototypes and measurements developed in all work packages, assuring a continuous information flow among tasks as defined in figure 5. Figure 5 shows the synergies and collaborations among tasks.

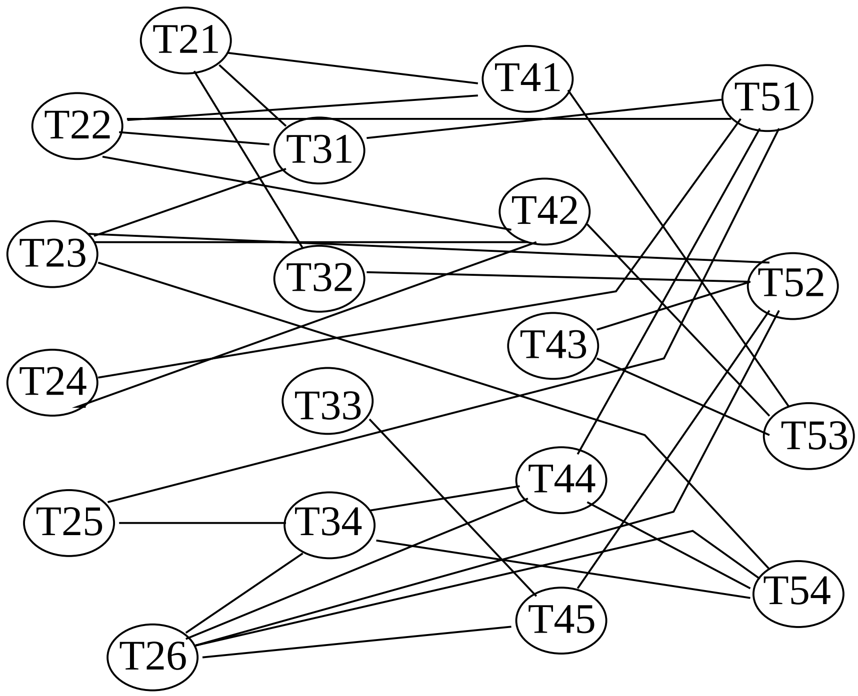

Figure 5: Most important Synergies and Collaborations among Tasks; connection between tasks inside the same WP are not shown.

Work Package 2: Planning Tools The approach taken in this work package can be summarized as follows. While the resource allocation problem for communication networks in general is NP-hard, for a particular and well-managed network the problem is actually easier. This is due to the fact that network traffic has regularities and that the network structure has been explicitly designed to fit these regularities. The research in this project concerns the question of how knowledge about these regularities and the intent of the network planner can be exploited to simplify the resource allocation problem.
Analogous methods are common in business organization: a common strategy is to structure problems into classes of tasks and resources such that all resources within a group can be considered equivalent. Algorithmically, this changes the complexity of resource allocation from NP-hard to linear in the number of tasks. Communication networks have a complex and meshed structure which makes such fixed structures infeasible. Furthermore, networks are easily modified and resource allocation methods must be continuously adapted to the current structure. The technology of knowledge-based systems, and more specifically constraint-based reasoning, is most suitable to specify the complex relations which arise in networks. These technologies will be used in a new type of net-

work planning tool which is capable of keeping a record of planning intentions. This network planning tool will be the main deliverable of work at LIA.

More precisely, research at LIA will concern the following tasks:

Task 2.1 Definition of resource and demand models. The elementary resources and demands are capacities on particular network elements. However, demands can be grouped into larger aggregates considering characteristics of the routing mechanisms as well as the demand structure. We will define a modeling framework which allows dynamic construction of such aggregates depending on the criteria. Collaboration with TCOM and LRC will ensure that this framework is compatible with existing or likely standards in ATM networks.

Task 2.2 Network planning tool. The purpose of network planning is to obtain network structures which match the traffic structure as well as possible. Thus, network planning starts with a specification of traffic patterns and constructs a plan of how these traffic patterns will be allocated to the network. Based on the models defined in task a), we will implement a prototype tool which will act as a workbench for a network planner.
It allows a user to formalize the known or expected traffic patterns and to synthesize a network consisting of resources that match these patterns. This process is similar to that developed by Choueiry for personnel allocation.

Task 2.3 Definition of possible allocation strategies. The intentions recorded in the network planning tool lead to a collection of allocation strategies which should be followed in the medium- and short-term. In this task, we will construct the translation from the formal specifications defined by the planning tool to a form which conforms to the standards usable by medium- and short-term allocation algorithms. These might consist of allocation choices for particular types of requests given certain activation conditions.

Task 2.4 Intelligent Analysis and Simulation tools. An important aspect of network planning is that a network is not only usable for a single traffic pattern, but for different patterns at the same time. It is also important to analyze contingencies such as failures of parts of the network and to optimize its response to such situations. This process can be supported by intelligent simulation tools which are again capable of recording the intentions of the network planner for modifications made at this stage.

Task 2.5 Learning traffic patterns. In this task, we consider the feedback of actually observed traffic patterns to the network planner. We will develop methods for comparing actual traffic with the expectations defined by the traffic planner and for expressing the discrepancies in concise forms which can be exploited for modifying the network structure.

Task 2.6 Implementation on a test network. Towards the end of the project, we will test and demonstrate the ideas on an actual ATM network and use the measurements from WP5.

Work package 3: Resource Management in short and medium term Resource allocation for an ATM or RSVP network has to solve a number of issues that are related to the support of integrated services with a packet (RSVP) or cell transfer mode (ATM). Integrated services require guarantees about delay, throughput and loss, which are difficult to obtain with such transfer modes. On the other hand, it is expected that packet or cell transfer modes will support statistical multiplexing and thus take advantage of traffic burstiness to increase network efficiency and reduce costs.

At the heart of the problem lies resource allocation for statistically multiplexed services like ATM-VBR or ATM-ABR. Connection acceptance mechanisms and routing for such services is based on a number of assumptions about traffic patterns: this is the case for example for the sigma-rule (Siemens) or the equivalent capacity approach (IBM). One key problem is the definition of control mechanisms that match the parameters of such mechanisms to the actual traffic patterns. Another key problem central to the concept of vertical integration, concerns the support for revenue optimization; based on input from the planning tool, the short term mechanisms will accept or reject connections based on expected blocking probabilities for the highest revenue generating services.

It is essential that resource allocation mechanisms do not burden the network with a large number of data and functions. Solutions for reducing the real time and storage costs associated with the mechanisms will be defined. More precisely, research at LRC will focus on:

Task 3.1 Resource Allocation in the short and medium term. Connection acceptance algorithms and methods for statistical multiplexing will be reviewed and a modeling method will be identified for the purpose of controlling the adequacy of the method to the actual traffic. Traffic measurement entities will be defined (virtual leaky buckets, network filters), and a feedback loop to connection acceptance and routing will be specified.

Traditional methods for resource management (sigma-rule, equivalent capacity) rely on explicit traffic models; the reality of traffic measurements tend to indicate that the assumptions underlying such methods are seldom satisfied. In contrast to these methods, we will use a two step approach:

- envelopes based solely on known parameters will be identified. For VBR traffic, the known parameters are sustainable and peak rates, with their associated tolerances,
- over-booking beyond the envelope will be gradually increased.

The method will be applied to specific examples such as the support of VBR and ABR connections in ATM, of RSVP flows over ATM connections.

It is the function of the traffic measurement entities and the feedback loops to control the over-booking and maintain it in safe regions. The modeling will identify structures to represent and translate the planning intentions expressed by the long term mechanisms.

Task 3.2 Traffic Characterization. Key traffic patterns will be defined, as well as appropriate models that are required for simulation and validation. Fractal, Brownian motion or Markov models will be used as appropriate.

Task 3.3 Implementation of Short Term resource management for reducing connection handling costs. The routing and connection control function may become a serious threat on network performance if they are not implemented with care. On demand routing is the simplest form of route computation, however it is known that it severely impacts connection latency. Connection acceptance and routing can benefit of methods for reducing connection awareness; the implementation of the mechanisms defined in a) will be based on such methods. In the ATM case, this means using virtual paths as a support mechanism; in the RSVP case, this means supporting several RSVP flows over single ATM connections. Definition of the dynamic topology based on those mechanisms will reflect the planning intentions and revenue optimization strategies of the long term mechanisms.

Task 3.4 Platform. In order to test and evaluate the mechanisms for resource allocation, an evaluation platform will be implemented. It will support simulation of network configuration and discrete event simulator reflecting network changes as well as user behavior.

Work Package 4: Network Management Architecture Current management systems pursue a platform-centered paradigm, where management agents monitor the system and collect data, which can be accessed by applications through management protocols. These data are stored in a management information base (MIB). However new and evolving management applications require a decentralized approach. A good example of an application that requires decentralization is the use of RMON (remote monitoring) [43] probes. RMON probes collect large amounts of information from their local Ethernet segment, and provide a network management system with detailed information about traffic activity on the segment. A way to reach this decentralization objective is delegation [43].

Delegation consists in down-loading of programs to a remote management agent, binding them with its local environment and executing them under local or remote control. Delegated programs provide flexibility of the management and control intelligence embedded in networked systems. Delegation can be used to move management functions to the data and execute them by the agent rather than move data to these functions. For example, an agent can be delegated to an ATM switch to monitor and analyze the virtual-circuit tables and execute fixes locally. This agent can access the MIB data more efficiently and reliably than a remote platform would do. For example, it can be used to implement a local control loop, rather than stretch it over the network, thus benefiting from reliable, low-latency and high-throughput access. This delegation approach is mandatory for ATM based-networks management where SNMP MIB tables (resp. OSI MIB objects) of thousands of entries (resp. instances) may be present (e.g. virtual circuits) in a single node. This delegation approach will be used to design a distributed network management architecture for vertical integration of network control, management and planning. Tools to develop a management agent oriented language will be the main deliverable of work from TCOM.

More precisely, research at TCOM will concern the following tasks

Task 4.1 Definition of a management agent oriented language. Current Internet and OSI MIBs are defined in terms of a language that structures management information (SMI) [44] [45]. Management protocols [46] [47] provide a data manipulation language to query MIBs, which is very basic. However delegated agents will need a data model that is very flexible, which is far from being that of current network management standards. There are approaches to transform MIB data [48] [49] but these only propose partial solutions to the problem. Therefore, our first task within this project is to propose a specification language providing richer semantics than the standardized ones, for developing management applications that will be processed by delegated management agents.

Task 4.2 Validation of specifications. The second task will be to validate the specifications of management applications developed with the proposed language, before introducing them in the management architecture. It consists of defining how to express constraints on a management application specification. These constraints represent the conditions in regards to which the management application specification and design can be validated. The output of this task will be the definition and implementation of a translation method between the proposed management agent oriented language and the Promela language supported by the validation tool Spin [50].

Task 4.3 Management framework. Based on the concept of delegated agents, a management framework will be developed reusing concepts of TMN [51] such as management layers to partition the total management activity, information models within these layers to have a data representation of network resources for the purpose of management, and so on. Delegated agents will be deployed in the management layers and will encapsulate information models.

Task 4.4 Application to particular management functions. This task will concern the realization of management applications such as fault, configuration or performance management for ATM-based networks with the obtained tools.

Task 4.5 Study of the interfaces with short term and long term management.

- With short term management. ATM network management and ATM traffic control are separated. Indeed traffic controls are performed automatically by the set of real time algorithms with response time of the order of microseconds while management tasks are inherently slow and may sometimes involve (if automated network management tools are not provided) a human manager. However, these traffic control and network management operations interact with each other. Indeed the former can provide to the latter some important information for performing management functions. For example, concerning accounting management, the details of contract violation provided by UPC (Usage Parameter Control) should ensure user tariffing. Thus, whenever a user deviates from its negotiated terms, the network management module should be notified from UPC with details of the violation. Therefore this subtask should identify and specify how network management (TCOM) and traffic control (LRC) should interact.

- With long term management. The management functions should provide statistics that will be processed by analysis tools according to strategic objectives. Therefore this subtask should identify and specify how network management (TCOM) and planning (LIA) should interact.

Work package 5: Technology Transfer The main goal of this package is the technology transfer, that is:

- providing the real-world requirements for the tools, such that it is possible to incorporate them into the toolkit under development at the Swiss TELECOM PTT research and development laboratory,
- incorporating the results in our own toolkit,
- developing future service management architectures and procedures for resource management of future services and networks.

Some of the approaches developed for enterprise network design and optimization are applicable to service management (in particular resource allocation) too.

Task 5.1 Tool and method development.

Determining the real-world requirements, and assure that the results are applicable. Integration of the results from work package 2 in our own toolkit. This includes the adaptation of the results to our (internal) customer needs. This activity provides valuable feedback for the other partners.

In addition, confidential aspects and tool features are developed in-house in conjunction with this task. Naturally, these results will not be (directly) available to the other project partners.

This activity terminates with a field trial for evaluating the developed methods and tools.

Task 5.2 Network and Service Management.

In the future the responsiveness of a service provider is essential. This means that the boundaries between network planning and management change. In this activity, the consequences and opportunities for the service management are studied in the light of the results from the other work packages of this project. This complements ongoing efforts in this important area. These efforts provide valuable insight about the real-world requirements for this project.

Task 5.3 Interaction of Delegated Management Procedures.

In the network management by delegation approach, it is necessary to evaluate the result of the combination of management procedures delegated by different network managers to a single agent. In this activity, these interactions are formalized in our formal representation language for software function to evaluate this language as a solution for some of the aspects of the management oriented langue developed in work package 4.

Task 5.4 Integrated solution for both LAN and WAN. The experimental multimedia communication platform developed into the ETHMICS project is based on distributed object. For ATM-oriented networks, an object-oriented framework serving as a distributed kernel operating system, with QoS-determined resource allocation has been developed [41]. This object oriented model will be compared with the results of working packages 2, 3, and 4, in order to obtain an integrated solution suitable for both LAN and WAN networks.

2.2.4 Importance of this work

It is often said that the robust structure of the Internet is a result of its organic growth similar to a living organism. However, while in nature it is feasible to add structure in small increments, in communication networks it is most economical to construct the structure out of fiber optic cables capable of carrying thousands of communications. Organic growth of networks therefore often results in poor service, as can be observed in the Internet. This project will make an important contribution towards improving this situation. It addresses the important problem of how to plan a network, and how to manage its resources according to this plan.

Another aspect of this project is its contribution to fundamental research. Resource allocation is a problem of great economic importance in many areas. Solutions have been developed either in the form of fast but unreliable heuristics, or in the form of very slow optimization algorithms. Both are unsatisfactory in practice: it has been proven that there can be no good approximation schemes for resource allocation, thus for any heuristic there will always be scenarios where it will perform arbitrarily poorly. On the other hand, optimization algorithms are too slow for practical problems. The approach developed in this project, using a hierarchy of abstractions, is a promising alternative for this field in general.

For the Swiss TELECOM PTT and its UNISOURCE partners this project is important due to the following reasons:

- in the case of ATM, the boundary between the corporate networks of the TELECOM PTT's customer and the public network as well as the boundary between the planning activities at the different levels are not yet well understood. Therefore, the project is important for sizing the opportunities of the new technology and developing the necessary tools and methods for effectively planning and efficiently managing corporate customer networks and our own networks.
  This project is complementary to our own substantial efforts (carried out in cooperation with the University of Bern) on tools and methods for designing enterprise networks, in particular ATM-based ones, on developing abstractions for network planning and performance management (in cooperation with LIA),
- provides the foundations for competitive services based on ATM.
- strengthens the position of the Swiss TELECOM PTT within UNISOURCE, because without sufficient strength (critical mass, timely and high quality results), it is likely that the Swiss TELECOM PTT would loose in competitiveness, compared to the PTT of the other countries.

2.3 International collaboration

2.3.1 International projects

The Swiss TELECOM PTT is involved in the UNISOURCE international partnership, and is now member of the International Computer Science Institute (ICSI) in Berkeley.

2.3.2 UNISOURCE Participants nationality

The UNISOURCE partnership is a company in which the Swiss TELECOM has a share. The other partners are the Sweden (Telia), Netherlands (dutch PTT), and Spain (Telefonica).

2.4 Summary of Research Plan

See page 4.

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3 Valorization

3.1 Own efforts

The Swiss TELECOM PTT, as a partner in this project, will directly use the results of this research. The project strengthens the position of the Swiss TELECOM PTT in the UNISOURCE partnership, such that Switzerland profits in the form of increased employment too.
The fundamental research results concerning resource allocation, abstraction, structure of network management applications are applied to other network planning and management tasks and future network management systems, respectively. The applicability of the results is assured by TELECOM PTT participation, that brings in the project the real-world requirements. This results will be used in other projects of EPFL and could lead to other applications. The competence center at EPFL will also use the results of this project in lectures of Section de Communication and Section Informatique.

3.2 Measures for transfer to other groups

The results of this research will be published in the international research community.

3.3 Which other aspects may be of interest to others?

The concept of solving combinatorial decision problems in real time by precomputing a hierarchy of restricted solution schemes could be applicable in many other areas. Another interesting result could be the abstractions on graphs which will be developed in the course of this project.