New Generation Network Architecture and Software Design

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ABSTRACT

This article deals with new telecommunications networks, the reasons for changes, and the options telecommunications are facing today. The new generation of network architecture is discussed, and two network evolution case studies are presented as well as the new role of powerful applications in the future development of networks. Special emphasis is on software research and development supporting this "new telecom world."

INTRODUCTION

The telecommunications marketplace is changing at a speed that was inconceivable some years ago. Liberalization is leading to increased competition and new business opportunities for numerous players [1]. Changes in society and work habits impose on more and more people the requirement to be practically "always connected." New technologies offer more capacity and flexibility for faster and cheaper implementation of new features. All these factors support a booming telecommunications industry, which is growing at a rate of nearly 10 percent annually, significantly beyond average economic growth figures. These changes also have a profound effect on the way telecommunications networks are developed; a need has arisen for a new generation of network architecture that makes use of the technological advances, at the same time allowing for flexibility of implementation, reflecting the dynamics of the business drivers behind investment decisions.

The changes in the marketplace affect the wireline and wireless segments of the market alike. In pure numbers related to capacity and number of users, the wireline segment is still growing at a healthy rate. Wireless networks around the world are still struggling with capacity growth to meet the basic mobility needs of an ever growing customer base.

However, as the price levels of basic services, such as voice and pure bit transport, go down, and are expected to be charged at a flat rate in the near future, there is a growing need for innovative premium price services. Such new services are expected to emerge in the area of convergence of media and communications, stimulated by the fast evolution of microelectronics and software technology, supported by Internet-based techniques. These trends are most visible to end users in the wireless market, where portable multimedia based on futuristic handheld devices and new network services will be a reality in a few years, pushing the boom of subscriber growth into a new steep rise at the beginning of the next century.

As for the future network architecture, both revolutionary and evolutionary development has been foreseen. It is true that the new players entering the marketplace have demonstrated networks built from scratch, with Internet technologies deployed as an overlay to existing competing networks. For the majority of established wireline and wireless operators, however, the need to capitalize on the large investments made in networks is common business sense.

Introduction and deployment of new services in the network must be done at the speed required by the market. Therefore, the new network architecture must be an evolution of today's networks, with the new technologies introduced in a stepwise approach.

This presentation will examine the architecture and product trends of the future network, and discuss two case studies of how the new structures and technologies can be deployed in a network. Applications and services driving the network evolution will be presented, with several examples. Finally, the effects and implications of the new network architecture on research and development, especially in the field of software technology, will be studied.

THE NEW-GENERATION NETWORK: ARCHITECTURE AND PRODUCT TRENDS

The new network architecture consists of:
- An access layer
- A transport and switching layer
- An application and service layer (Fig. 1)

The access layer includes both wireline and wireless network technologies, while the switching and transport backbone provides basic connectivity. The application and service layer compris-

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es servers and databases that provide the intelligence required to manage subscribers and services, and control the connections.

A similar structure was introduced in terms of the intelligent network (IN) architecture in the 1980s. What now makes this architecture widely accepted as well as suitable for implementation on a broader scale are recent advances in technology, especially in microelectronics for access and transport enabling flexible extension of existing infrastructure, as well as new software and protocols, allowing a migration of existing applications and control functions on new flexible platforms.

In the following section trends relating to the access, transport and switching, and application and services layers will be examined further.

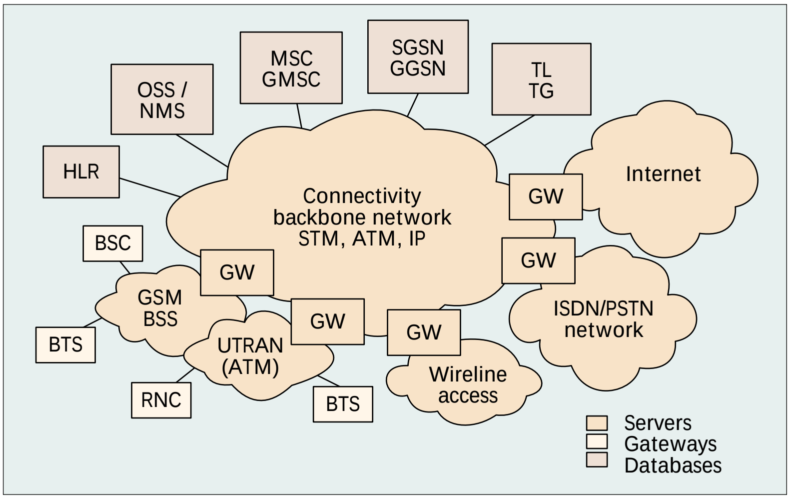


Figure 1. *The new network architecture.*

THE ACCESS LAYER

Only a few years ago the existing copper access network was deemed outdated, and future broadband services were expected to require fiber all the way to the home. Current advances in digital subscriber loop (xDSL) technology demonstrate that existing copper loops can provide several megabits per second downstream in data speeds, high enough to handle the majority of foreseeable services delivered by the current and next-generation Internet [2].

In parallel with the advances in access technology, new access products capitalizing on the "rebirth" of existing subscriber loops provide a variety of end-user accesses, integrated services, and open interfaces. An example of such technology is V 5.2, used for connecting to backbone and switching networks in the way most suitable for the network operator [3].

The success of second-generation digital wireless networks, especially Global System for Mobile Communication (GSM), has secured continued investment in the development of radio technology. The capacity of narrowband digital radio is continuously being increased through more flexible network implementation solutions, such as hierarchical cell structures and adaptive antennas. The introduction of packet-oriented radio technology, namely General Packet Radio Service (GPRS) in GSM, further improved by Enhanced Data Rates for Global Evolution (EDGE), utilizes the scarce radio resources within the existing frequency ranges more effectively, especially for data services. The evolutionary approach associated with GPRS, where existing infrastructure in the base station system (BSS) can be reused, allows for introduction of mobile data services on a broad scale.

With the Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (UTRAN), a new spectrum-efficient radio technology, wideband code-division multiple access (WCDMA), is introduced to continue the evolution of GSM toward third-generation capabilities. Although UTRAN is based on a new radio technology, its flexibility in siting and transport allows significant savings in radio access investments.

THE TRANSPORT AND SWITCHING LAYER

Basic (optical) transmission technology has an important role in the new-generation network. In this area wavelength-division multiplexing (WDM) has in the last two years shown opportunities to increase the capacity of existing transmission networks by a factor of 100. Hence, a perceived bottleneck for future network applications has effectively been removed.

Within the backbone transport network the discussion on the cost benefits of packet-oriented technologies vs. the quality of service (QoS) offered by circuit-switched networks continues. Advances in router capacity and voice-over-IP (VoIP) applications have convinced a number of new entrants in the operator market to introduce overlay networks targeting selected customer groups. Several established network operators have also launched network evolution programs, introducing packet switching in a controlled way on the existing networks. Asynchronous transfer mode (ATM), as a packet-switching technology offering QoS and good network management mechanisms, plays an important role in facilitating this evolution [4]. With ATM interworking closely with the existing circuit-switched call control infrastructure, it is possible to flexibly introduce packet switching as a basis for new applications in parallel with the current public switched telephone network/integrated services digital network (PSTN/ISDN). This ensures retained QoS and reuse of the existing functionality for telephony.

THE APPLICATION AND SERVICE LAYER

An important issue in the new-generation network architecture is the independence of applications and services from basic switching and transport technologies. The trend described is expected to continue and deliver new solutions, for the ever increasing amounts of data being communicated. Therefore, a separation of applications and control mechanisms from the access and transport layers is the fundamental feature of the new architecture. On the application layer several trends are visible, pertaining to the different segments of the market. IN still plays an important role for well specified services, especially mass market services requiring high capacity and good management control. Examples of this are number portability and prepaid

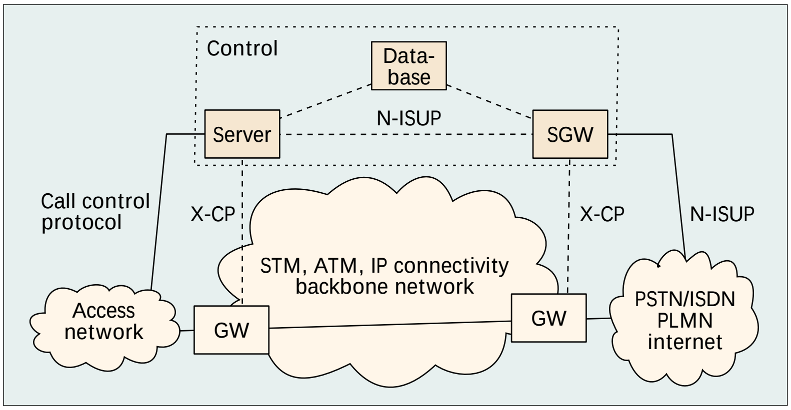


Figure 2. *The separation of control and connection.*

services. Many future services require more flexibility and small-scale economics in their introduction. Dedicated servers and standalone nodes already offer these capabilities for many new services today, especially within the wireless networks.

The current implementation of the application structure, however, is becoming more and more complex to manage and requires a new approach. The next significant step toward the new architecture involves the true separation of control and connection (Fig. 2). This is made possible through the migration of applications and call control functions on open platforms, the introduction of common control protocols to support communication between control functions and network resources, and especially through the introduction of media gateway (MGW) nodes.

MGW nodes provide conversion between different communication media, protocol adaptations, and pooling of devices such as codecs and announcement equipment (Fig. 3). The gateway nodes will be developed in different configurations and implementations based on the applications, but they should fulfill telecommunications-specific design requirements and reuse network infrastructure when applicable.

The main characteristics of the above described network architecture are as follows:

- Application-driven: separation of control and connection, and business aspects driving the speed of implementation
- Server-oriented: the opportunities to introduce new services both through servers connected to the network and by porting existing telecommunication logic on open server platforms
- Software-dominated: due to the expected increase of higher-level programming and amount of source code used and/or reused for implementing the application layer and corresponding protocols
- Service-differentiated: the need to offer new applications at a rate expected by different market segments as well as support different levels of QoS, depending on the price end customers are prepared to pay

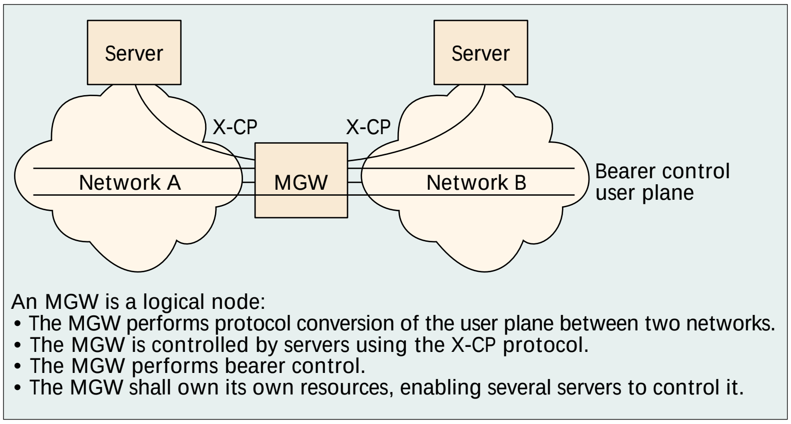


Figure 3. *Media gateway principles.*

Two Case Studies in New Network Architectures

The introduction of the hybrid switch and UMTS into existing networks illustrates possible scenarios for the network evolution strategy.

The Next-Generation Network

Several established telecom operators are driving a network evolution strategy based on the introduction of packet switching in the backbone network as the most cost-efficient and flexible way of dealing with the change in traffic volumes.

The network vision that forms the basis for the new architecture is based on a multiservice access network, reusing the current access and local switching network to the greatest possible extent. The connectivity network on the transport layer is to be based on ATM over synchronous digital hierarchy (SDH)/WDM, on top of which legacy applications such as X.25 and telephony services as well as new IP-based applications are to be ported and further developed.

From the implementation point of view, the next-generation network will be based on existing circuit-switched nodes in the local network and the introduction of hybrid circuit-switched and ATM nodes on the transit level (Fig. 4). The hybrid nodes provide a flexible way of introducing ATM as a basis for the packet-switched network, ensure the QoS of voice traffic, and at the same time reuse a significant amount of software-based telephony-specific applications such as signaling protocols, IN features, and charging functions.

The next-generation network will be implemented in phases, ensuring fast rollout of the ATM backbone and introduction of hybrid nodes in 2000.

Introduction of a UMTS Core Network Based on an Open Architecture

The development of UMTS is now increasing in speed as relevant standardization decisions related to the core network architecture are being made [5]. The development of the radio network products has progressed fast due to early agreements on the specifications and interfaces, which led to the implementation of a number of test systems worldwide in 1998. The new wideband radio access network based on WCDMA and ATM transport is introduced into the network as a complement to the existing GSM BSS, with a new standardized interface (Iu) toward the core network elements, the mobile switching centers (MSCs) and GPRS switching nodes (GSNs).

The UMTS network architecture is fully compatible with the new network architecture described above, and allows for migration of existing functionality and network resources in a controlled way to the new open architecture (Fig. 5).

The migration can take place gradually, where the first step involves the introduction of ATM into the backbone of the GSM network. In the next step the UMTS radio network, UTRAN, will be introduced, with the standardized interface toward the core network based on ATM transport, allowing for effective transmission resource planning (Fig. 6).

The third step introduces the MGW nodes at the edges of the network. This permits the placement of transcoders for UMTS at the edges, and thus leads to cost-effective use of transmission resources and speech processing devices. It also paves the way for the next step, adding IP as a common base for communication between network nodes. The MSC/visitor location register (VLR) functionality can in this phase be migrated onto open platforms, supporting a server-based application architecture. Further on, a server-based application architecture links the mobility management functions with database functions such as location registers and service nodes (Fig. 7).

The evolutionary approach associated with the introduction of UMTS will lead the implementation of the new network architecture, and it constitutes a reference for a new generation of software-intensive products based on open platforms.

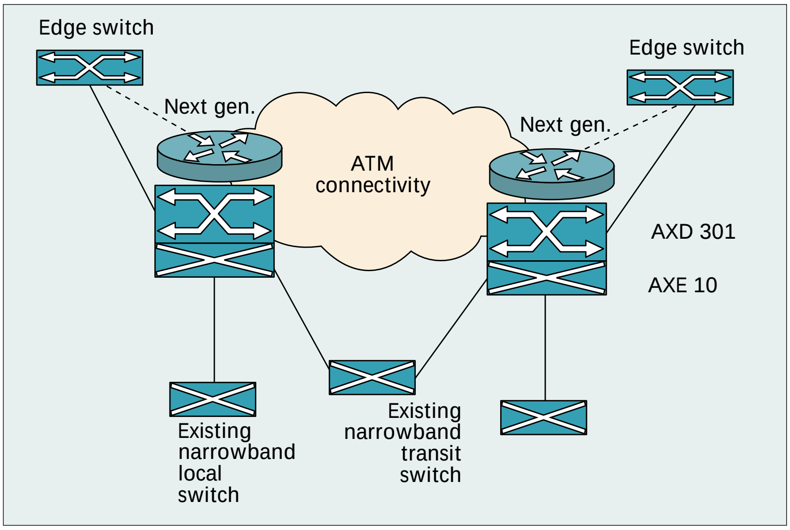


Figure 4. *A hybrid next-generation network.*

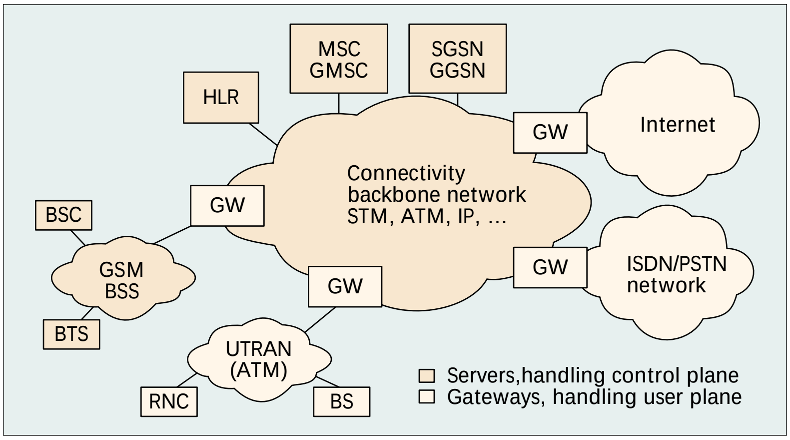


Figure 5. *A UMTS core network.*

SERVICES AND APPLICATIONS

Telecommunications systems are getting closer and closer to their final boundaries, mainly because of the gap between current and needed powerful, productive applications and network services. The current application and network services concept dates from the beginning of the '80s, when the digital, stored program control (SPC) switching network architecture was developed. This concept was based on the assumption that applications and services should reside within the network, primarily because of the limitations in architecture, capacity, price, power, and memory of the computers available at that time.

In spite of the fact that this concept has been continuously improved over the years as a result

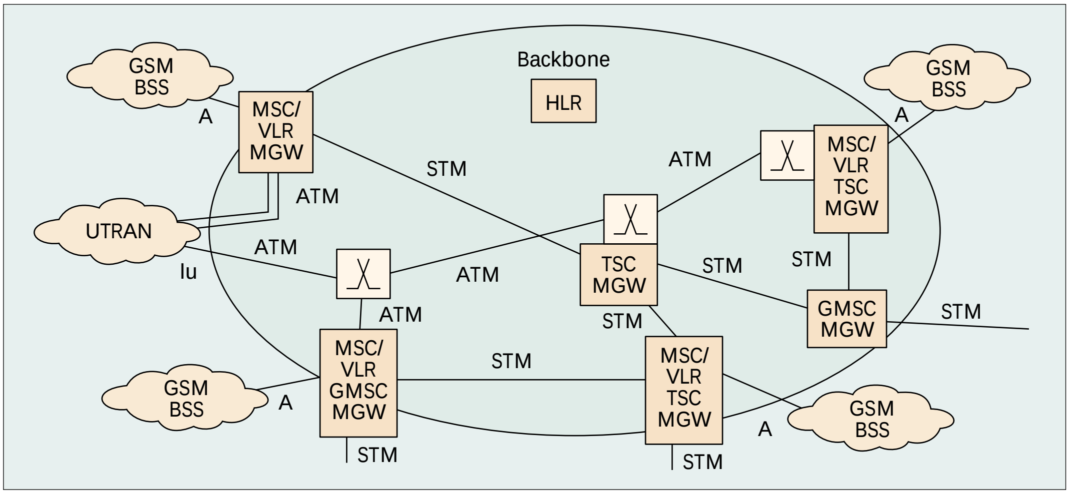
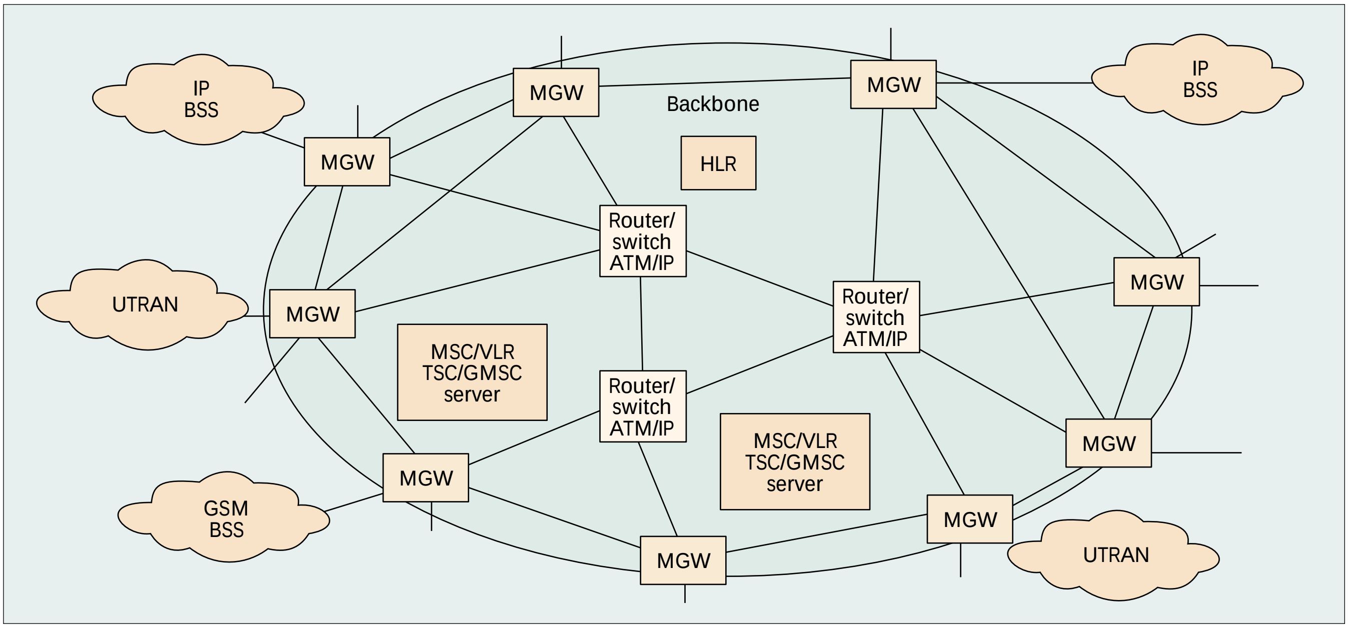


Figure 6. *GSM to UMTS migration: the introduction of UTRAN.*



■ **Figure 7.** *GSM to UMTS migration: MGW and IP added.*

of such new technologies as fiber optics, powerful microprocessors, and cheap memories; and in spite of the fact that both the telecommunications and computer industries have recognized the problem, it seems that this problem is today bigger than ever. From our point of view, the computer industry has focused on developing new, powerful applications for individuals and the mass consumer market, while at the same time the telecommunications industry has been increasing bandwidth mainly for the business segment. The focus on business customers in telecommunications is obvious, since they create 80 percent of revenues.

Thus, the mass consumer market has been left without enough bandwidth and the business segment without appropriate network applications.

The increasing power of computers and continuous development of software technology creates the possibility to develop more powerful and productive applications. However, a prerequisite for these applications is their effective mutual communication. The new network should have the capacity, common interfaces, and protocols to support this interaction in a seamless manner. Of course, the new network should support any type of application, such as combinations of voice, data, video, music, fax, and telemetry.

The development of services and applications will be driven by end users, whether they represent the business or consumer segments. This means that when launching a new service, it is important to cover all aspects — from network implementation to usability — from an end-user perspective, as well as marketing aspects and business case evaluations.

The ability to develop and deploy new services and applications in response to market demands will become a key factor of success in the future. As bandwidth becomes a commodity, the competition in the telecommunications market moves to the level of creativity, flexibility, and managing complexity and speed. These depend on the flexibility of software architectures as well as competence in understanding the complex nature of new services and applications. This development will occur on several planes, and will have to cover areas such as signaling, traffic engineering, network reliability, security, management, monitoring, pricing, and active networking.

It is clear that in the coming years the new telecom world will be influenced very much by new applications based on the contents and processing of information. Development of new applications such as distance learning, e-commerce, digital libraries, and virtual reality require a combination of skills and components from several domains within the telecommunications, information technology, and media industries. We would like to underline e-commerce, which could affect every part of our lives, and virtual reality as very promising applications; this will be explained further through a case study. This study is a result of cooperation between the Center for Advanced Computer Studies, University of Louisiana at Lafayette, United States; and the Department of Telecommunications of the Faculty of Electrical Engineering and Computing, University of Zagreb, Croatia; and it is a starting point for further common research between the above-mentioned universities and Ericsson.

Distributed Multi-User Multimedia and Virtual Reality Applications

A general framework for distributed networked multimedia and virtual reality applications is proposed. The general framework has been specified using the Unified Modeling Language as a tool to describe two interrelated models, the functional model and the interconnection model. The functional model concentrates on the distributed virtual environment functionality, while the interconnection model concentrates on how

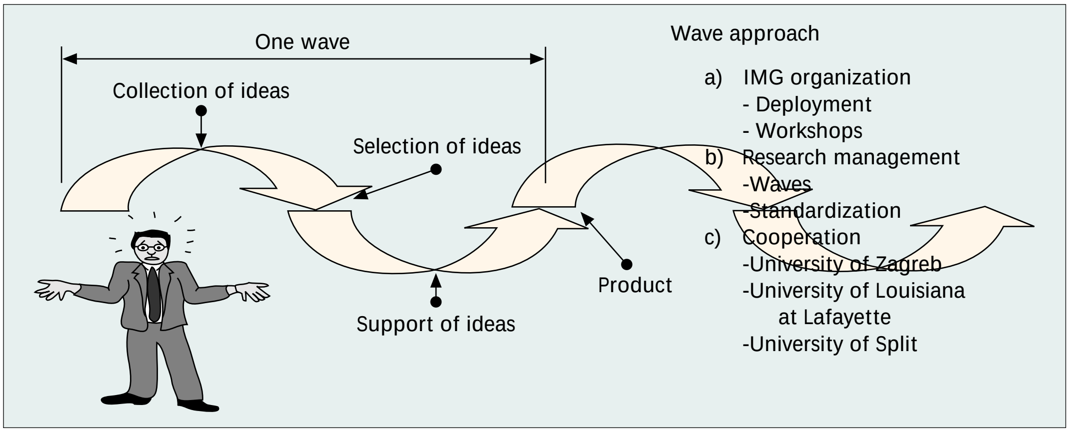


Figure 8. *The Ericsson Croatia innovation approach.*

the components are interconnected to realize the required functionality. The two models provide a basis for identification and specification of a set of qualitative and quantitative parameters used as QoS characteristics. These parameters help evaluate the user's perception of the virtual environment and relate it to measurable network and application-level parameters, which provide a basis for evaluation and comparison of VR applications. Two application development case studies demonstrate the use of this approach, utilizing recent standards in distributed simulation and virtual reality. In the case studies, networking issues have been addressed in two different ways: one implements a set of messages and uses them to explicitly transfer information over the network; the other specifies data structures to be used in applications and leaves to the underlying programming interface all network-related issues [6].

Requirements and Expectations for Products in the New Architecture

Customers' requirements and expectations for the next-generation network and its elements require a completely new concept for research and development organizations. In addition, sales, engineering, installation, and maintenance as traditional activities should be changed into marketing and sales, consulting, integration, operations, and system support as a result of the request for new, high-value, revenue-generating products and applications.

To fulfill this demand, creativity and innovation are becoming leading elements of successful companies today. Since it is not possible to know from whom, when, and how an idea will come up, it is necessary to introduce organized innovation management. The basic purpose of innovation management is to increase the probability of creating new ideas by motivating people to remove personal and organizational barriers. The so-called *wave approach* innovation process (Fig. 8) was recently defined, and innovation management has been introduced within Ericsson Croatia, resulting in a dramatic increase in the number of ideas and new products.

The goals of Ericsson's innovation management are:
- To encourage creation of new ideas
- To establish cooperation with customers
- To establish cooperation with universities
- To establish intergroup coordination
- To establish cooperation with international standardization bodies
- To collect new ideas
- To analyze new ideas
- To analyze customer perspectives on ideas
- To ensure a short "time to idea"
- To support the start of research projects
- To support the start of development projects

In order to ensure success it is necessary to involve customers from the very start, and ensure close interaction and cooperation during all development phases.

The second leading element is, undoubtedly, the quality of products and their in-service performance from a customer point of view. These elements were the focus of a continuous improvement program that has achieved good results over several consecutive years. The continuous improvement program is based on measurements of performance and the capability of processes, relating to indicators such as fault density, lead time precision, productivity, and creativity. The main activities of the program are diagnosis and root cause analysis based on the "learning from mistakes" concept, definition of a few vital actions within the "best practice" concept, and on deployment of these pursuant to the total quality management concept.

The final leading element of change is the time to market for new products and applications. The competition simply cannot accept a development cycle of several years. A lead time of three to 12 months for a new service, depending on the complexity of the problem, is what the market expects. For research and development organizations this implies that there is no time for traditional research, results analysis, and subsequent start of development.

In short, there is no time for the conventional transfer of technology between the phases. Also, marketing and sales as well as supporting activities should be proactive and present in R&D projects from the very beginning.

In order to achieve this, it is necessary to change the traditional waterfall development

Customers' requirements and expectations put on the next-generation network and its elements require a completely new concept for research and development organizations. To fulfill this demand, creativity and innovation are becoming leading elements of successful companies today.

It is evident that the new-generation network will be a "network of networks," based on a balance between invested infrastructure and the increasing demand for new powerful services and applications. The new network should offer both evolution for incumbents and possible revolution for newcomers.

model into a modern, fast, and efficient model like the incremental or spiral development model.

Besides speeding up standard development, it is also necessary to simultaneously introduce rapid development as an alternative process. This is needed in order to ensure fast (three to six months) development of small applications or simpler enhancements of already developed functions. This underlines the importance of highly competent, experienced, and skilled all-around players. Rapid development requires parallelism and teamwork, and removes boundaries between different phases of the development process.

Finally, we should not forget the development of the design environment, which has to support the increased software development productivity and the development of more flexible software, based on interchangeable and smart self-controlled components.

CONCLUSION

It is evident that the new-generation network will be a "network of networks," based on a balance between invested infrastructure and the increasing demand for new powerful services and applications. The new network should offer both evolution for incumbents and possible revolution for newcomers. It seems that the future network will be composed of several technologies, with ATM in the backbone, complemented by circuit switching in access and legacy telephony applications. The introduction of IP will be crucial to opening up the network architecture for faster and more flexible application development. Future development will be characterized by a convergence of telecommunications and computer technology, strongly application-driven. This will change software research and development concepts to increased creativity, innovation, productivity, quality, and speed.

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