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Future Trends and Perspectives in Information Networking: Towards Global Broadband Networks and Services

The telecommunications industry is currently characterised by major challenges and opportunities, and by great technological and organisational diversity, which is mainly due to the deregulation of its markets, and the progressive convergence of telecommunications and distributed computing. Consequently, there is a growing demand for a great variety of new sophisticated telecommunications services. TINA-C and personal communications services (PCS) are among the most important developments in the field of information networking, which promise to make the future open information market a reality. In this paper, after a brief analysis of important information networking aspects, both of these developments are examined focusing especially on their future perspective. Therefore, possible enhancements of TINA-C through the use of frameworks, design patterns, and agent technology, together with the application of programmable intelligent service infrastructures in PCS are considered. Finally, the need for technology integration, joint action, consensus, and cooperation is highlighted.

Introduction

Due to rapid technological development, market growth, and deregulation the telecommunications industry is heading towards a fully liberalised global market, where regulatory changes are breaking down the traditional barriers between public and private domains. The result of this liberalisation is a fragmented market with a multiplicity of competing and/or cooperating providers of telecommunications services. Increasing customer needs press for the creation, operation, and management of many types of services, ranging from simple telephony services to new advanced multimedia telecommunications services (telematic services).

In this highly-dynamic continuously-changing open environment, which is shaped by the convergence of information and telecommunication technologies, a steadily growing number of increasingly powerful communication and information services is being offered. In this context information networking is gradually gaining momentum, formulating an open market of new telecommunications services where the vision is 'information any time, at any place, in any form'[16]. Within this electronic market, which is an important precondition for the emerging information society, information resources are available to everybody, without any practical restrictions, because, in an all-digital environment, 'there is no difference

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between bits which represent text, audio or video, since bits are bits'[20].

This paper examines the most important trends in the field of information networking, focusing especially on the perspectives of the framework defined by the Telecommunications Information Networking Architecture Consortium (TINA-C), and personal communications services (PCS). The application of programmable intelligent service infrastructures, like TINA-C, in third-generation mobile systems, will result in the efficient support of a variety of service engineering activities, involving both fixed and mobile services, in an environment open to competition, and open to changes in market and technology.

Information Networking: Services and Infrastructure

The innovative developments that are taking place in today's diversified telecommunications world are simultaneously driven by progress in network/system architectures and software (technology push), and by the need for more universal and personal communication and information capabilities independent of location and time (market pull)[3, 6].

To pave the way to the information society, it is necessary to define and develop a telecommunications service infrastructure (an information network), above the bearer network infrastructure, which will control and manage the distribution of information, in its various media manifestations, between geographically distributed user entities. This is the task of information networking, which more specifically is required to[2, 6, 17]:

- offer a rich variety of telecommunications services, including conventional telephony and data transmission services, as well as advanced multimedia services;
- provide and support new communication concepts, such as conference services, distribution services, and personal mobility;
- hide the complexity and heterogeneity of the underlying computing and networking technology;
- meet the scalability, reliability, and performance requirements of the customers;
- permit management by different stakeholders, such as service providers, network operators, and customers;
- allow user access to personalised interfaces from any point in the network;
- allow roaming, such as that found in cellular telephony networks;
- support the transmission of many media types, such as voice, text, still, and moving images; and
- provide openness to all types of end-users, to all types of services and applications, and to changes, in time or space, of service software and hardware.

Telematic services have a central role in information networking. A telematic service is considered to be a geographically distributed entity (actually an encapsulation of a number of cooperating entities distributed over a geographical environment) providing a number of people (users, subscribers) a predefined carefully-selected set of facilities regarding the integrated coverage of a (possibly) wide range of information and communication needs, utilising the resources of (existing and future) telecommunication networks[1].

Among the virtually limitless variety of existing and future telematic services, those with multimedia characteristics enjoy currently a great demand. People recognise that multimedia telematic services with enhanced content can offer them powerful support for communication, information, education, entertainment, and cooperation. Therefore, this kind of service is rapidly emerging, and is seen as an important and strongly increasing market in the office, at home, and on the move[3].

The efficient provision of multimedia telematic services involves a number of new technologies. These enable the necessary bandwidths, connectivity, flexibility, support of simultaneous and time-staggered sessions, improved negotiation and renegotiation procedures, as well as appropriate manageability. Furthermore, advanced transfer protocols are required to cope with the differentiated, changing, and unpredictable requirements concerning connections, bit rates, and qualities for the various information types involved in specific services.

A promising technology to support new telecommunications services in the office, at home, and on the move, including services with multimedia characteristics is asynchronous transfer mode (ATM). Beginning with data applications, ATM networks will increasingly address audio and video needs, too. ATM can be employed 'edge to edge' for public and private networks and 'end to end' including servers and terminals. Furthermore, ATM facilitates the smooth integration of networks from the local to the wide area, and is an especially promising technology for the local loop (wireless ATM)[23].

Another development that is of growing importance and should not be underestimated is the dramatic expansion of the Internet, and its corporate incarnations (intranets, extranets), together with the popularity of the World Wide Web. Graphical user interfaces provided by web browsers give the user a convenient, visual, easily manipulated interface to the vast repository of (any type of) information available at Internet sites throughout the world. The Web has therefore become the first worldwide multimedia communication system. Albeit (relatively) slow and sometimes unreliable, the Internet is able to support voice telephony and multimedia telematic services, such as videoconferencing. For fast responses and a much higher reliability level several solutions are emerging, like the IPng (IP next generation), TCP/IP over ATM, and cable-based Internet systems.

It is conceivable that the variety of existing and evolving networks will partially converge to establish full-service and application-ready networks. A common ATM core network could interlink the diverse access networks (including cordless and cellular mobile radio), integrated services digital network (ISDN), broadband ISDN, Internet/intranet and other data/corporate networks, as well as cable TV systems[3, 22]. This would be an important step towards the information infrastructures of tomorrow (for example, the European and global information infrastructure, EII-GII) that will enable people and systems to communicate securely with each other, any time, and anywhere with acceptable quality and at reasonable cost[4, 21].

The TINA-C Paradigm

The growing demand for a great diversity of broadband, multimedia, and multi-party telecommunications services, in the framework of information networking, requires the adoption of rapid, intelligent, and flexible service provisioning approaches. Therefore, an open universal service platform which supports both telecommunications and management applications is required. Such a platform will result in the 'virtualisation' of the (computing and communications) infrastructure, increasing significantly the proliferation of telematic services. A virtual infrastructure (VI) is the outcome of the adoption of a software perspective that embraces a much more dynamic and heterogeneous approach to the representation of information, the configuration of hardware and software systems that process it, and the binding of resources to its processing and distribution[24].

In full agreement with this perspective some of the world's leading telecommunications and information technology companies established TINA-C in 1993. The main objective of TINA-C is to define and validate an open, innovative, and coherent architectural framework (a long-term service architecture) that would address in an integrated manner service control and service management. This framework encompasses the long-term objectives of both IN and TMN, applies open distributed processing (ODP) standards and object-oriented design principles, facilitates the design and provision of services in a heterogeneous system and network environment with different domains of ownership, and ensures the introduction of new and enhanced services and their management, much faster and more efficiently than with current approaches[6, 12].

The TINA-C overall architecture encompasses basic design and modelling rules, which are applicable to a wide range of services, and decomposes the complexity of the problem space into a number of complementary (sub)architectures (computing, service, networking)[25]. TINA-C services are considered as software-based applications that operate on a distributed processing environment (DPE). This environment hides from services the underlying technologies and distribution concerns, and supports in this way the portability and interoperability of the service code. Therefore, a service is realised by a set of interacting service components (that is, computational objects interacting via their computational interfaces), which are distributed across different network elements. Service components can be characterised as service dependent or service independent. The former support features that are specific to a service, while the latter support features that may be common to a wide range of services[10].

To enforce the approach taken in TINA-C and to facilitate the corresponding service creation process the concepts of frameworks and design patterns are introduced and applied. A framework can be defined as a set of prefabricated services together with some architectural concepts that define the constraints to put these services together. The architecture includes the rules that can be used to integrate the single services and to define possible flows of control between them[19]. Design patterns represent abstract solutions for specific problem classes. They capture the static and dynamic structure, and collaboration of a group of objects. They can be defined in an abstract language-independent way[11]. While design patterns can be considered as a horizontal structure over a set of computational objects, frameworks can be considered as vertical, domain specific (for example, telecommunications specific) configurations of components.

In the case of TINA-C, design patterns can be defined by identifying groups of interworking service objects, where every group is characterised by a micro-architecture that determines the way the objects interact to provide a solution for the specific aspects of a subproblem that arises during the development of a telematic service. Furthermore, a framework can be defined as the overall architecture, which specifies how the identified configurations of service objects can collaborate to implement a solution for the whole problem. Thus, a framework is a kind of construction kit for complete or semi-complete telematic services. It has to be complemented and customised using inheritance techniques. As an example, the TINA-C service architecture can be defined as a framework. On the contrary, the access to the usage of a service is an example of a design pattern (access pattern). It specifies the object group of the access session.

The introduction of design patterns and frameworks in TINA-C implies the establishment of a common vocabulary and the definition of common design structures. They assist in reducing the scope of the problem-solving process in the case of service creation, because they support the identification of similar problems and similar solutions. However, design patterns and frameworks are abstract concepts. There is no guarantee that their usage will lead to design reusability, design portability, and abstract customisability. Furthermore, good design patterns and frameworks, like good inheritance hierarchies, cannot be invented in an easy way. They have to be chosen and designed very carefully[14, 19]. Otherwise, the introduction of insufficient and wrong chosen patterns and frameworks in the service creation process may hinder or even prevent the design and implementation of successful telematic services.

Besides design patterns and frameworks, another possible enhancement of TINA-C originates from the fact that in new telecommunications services, service personalisation and service interworking are of fundamental importance, because in that way customers are enabled to define when, where, for whom, and how they will be reachable or not. TINA-C is based on the concept of DPEs, but since DPEs operate according to the centralised client/server paradigm, they are relatively inflexible, and do not adapt well to rapidly changing, or customer specific requirements. A possible solution to this problem is the application of intelligent agent technology to TINA-C.

An intelligent agent is a self-contained software element responsible for performing some set of operations on behalf of a user or another program with some degree of independence or autonomy. This means that an agent performs specific tasks delegated to it, and therefore contains some level of intelligence. Additionally, agents operate asynchronously (they are often event or time triggered) and may communicate with the user, system resources, and other agents as required to perform their tasks[16].

Moreover, more advanced agents may cooperate with other agents to carry out tasks beyond the capability of a single agent. Finally, as transportable or even active objects, they move from one system to another to access remote resources or even meet other agents and cooperate with them. These agents are called *mobile* agents in contradistinction with fixed agents, which remain in a single location throughout their execution. Agent mobility is probably the most challenging property, which provides intelligent agents with the potential to influence the traditional way of communications and service realisation[10].

In TINA-C there is the explicit notion of *user agents*, which represent, both the end users within the system, and the contact points for users in order to gain access to services. Although user agents are fixed, they can interact with other user agents (via session managers) for service session establishment. In addition, there is also the notion of *terminal agents*, which should adapt communication services to the used terminal capabilities of the users.

For this reason, the transformation of TINA-C to a static agent-based telecommunications architecture (Figure 1) is relatively easy and straightforward. In such an architecture, the user agent is aware of the communication preferences (in respect to time, space, medium, cost, security, quality, accessibility, and privacy) of its user, and controls on behalf of that user all incoming and outgoing communications in respect to intelligent routing, information filtering, and service interworking. It also negotiates and cooperates with other user agents for establishing a communication session between the respective users. Furthermore, due to its service architecture, TINA-C seems to be an appropriate candidate for the incorporation of mobile agents, both for asynchronous information exchange and for the establishment of real-time information exchange[13].

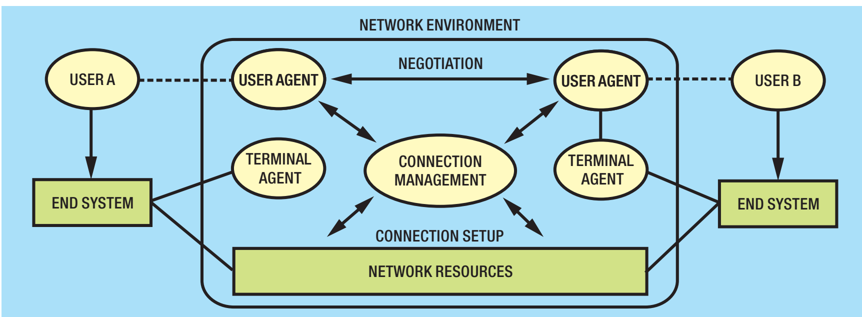
However, although intelligent agents and particularly mobile agents have a great potential to influence the design of future telecommunications services, they do not represent the ultimate solution for any kind of problem. Whether mobile agents provide for better performance than traditional client/server computing strongly depends on the interaction patterns and the 'size' (code plus state information) of the agent to be transferred[16]. Therefore, intelligent agents should be considered only as an enhancement or an 'add on' to TINA-C for the realisation of services under certain conditions.

Because of the flexibility in adapting new approaches and technologies, and because of its wide scope, TINA-C can be considered as a valuable complement to GII activities. Furthermore, it provides an architectural underpinning for the GII, as it is directed to the provisioning of any kind of services, running on a global scale, on different network technologies, allowing the combination of any kind of media and any kind of connectivity, and facilitating third-party connection setup and broadcasting as well as multiparty involvement. However, it has to be noted that the value and influence of TINA-C has been and will be measured by the extent to which it provides for industry-implementable results to accelerate the availability of TINA-like products. For this reason, the second phase of TINA-C, which started in 1998, focuses considerably on the market-driven adoption of the TINA-C architecture.

Personal Communications Services

The 'telecommunications services any time, any place' paradigm supported by rapid technological advances, propels the growth of wireless systems and networks. In full agreement with this paradigm, personal communications services (PCS) aims to provide personalised data, voice, image, and video communications services that can be accessed regardless of location, network, and time.

Figure 1—Static agent-based telecommunications architecture



The enabling factor to achieve this aim is mobility, which can be regarded in three dimensions[7, 9]:

- *Terminal mobility*, which refers to the ability of wireless terminals to access services as they move across different access networks. Moreover, these networks should be able to identify and locate a terminal and notify it for the initiation of new services.
- *Personal mobility*, which refers to the ability of a user to access telecommunications services on any terminal (wireless or wireline), according to a service or user profile, and based on a unique personal number dedicated to that user.
- *Service mobility* (called also *service portability*), which refers to the ability of the network to provide subscribed services to users irrespective of the type of the used terminal, location or access network. Service mobility requires both personal and terminal mobility.

PCS provide operations to service providers, subscribers, and customers/users through mobility, customisation, service profile management, communication, and security procedures[5]. As a result, personal communications services are characterised by the following key elements:

- *Ubiquitous connectivity:* A user is always able to connect to a network accessing the subscribed services, even if the access network or the used equipment are changed. Moreover, it could be possible for a user to have different active connections using different access networks simultaneously.
- *Single session abstraction:* The service remains the same throughout the session (or call) even if the access network or terminal changes (resulting in different quality of service (QoS) experienced by the user).
- *Application transfer:* Restoring an active application (or call) from one device to another as the user changes his/her location (for example, from office to car) or the used access network.
- *Application adaptation:* The session characteristics should change in order to keep an application active as the user

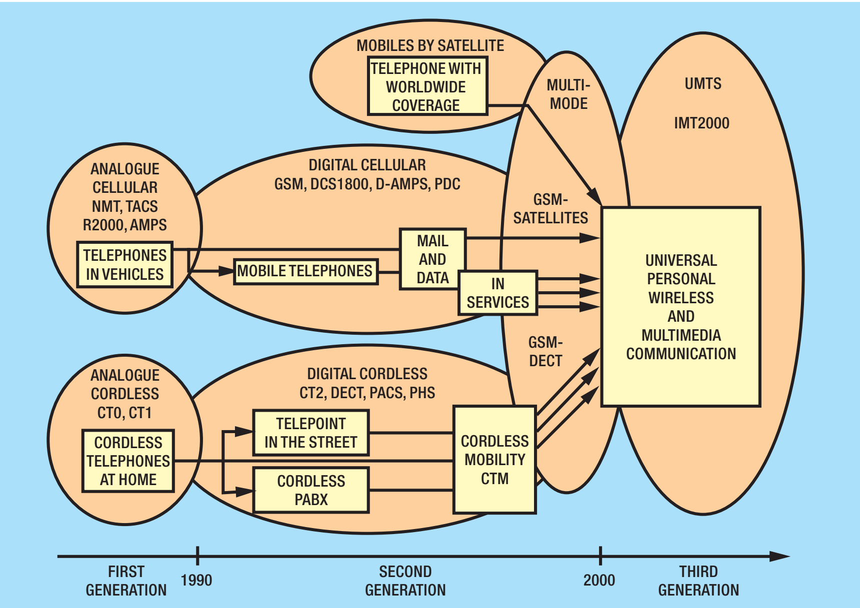


Figure 2—Evolution of personal communications services and systems[9]

changes device or access network. Adaptation could mean changing information content or changing media format. Changes in the information content can be triggered by a device change, which influences the available network bandwidth, the processing power, the memory capacity, and the display capabilities (for example, a less capable display as the user moves from a laptop to a mobile telephone could result in a drop of the video connection for a teleconference session). Furthermore, changes in the media format are imposed by media incompatibility (for example, moving from laptop to a conventional PSTN telephone).

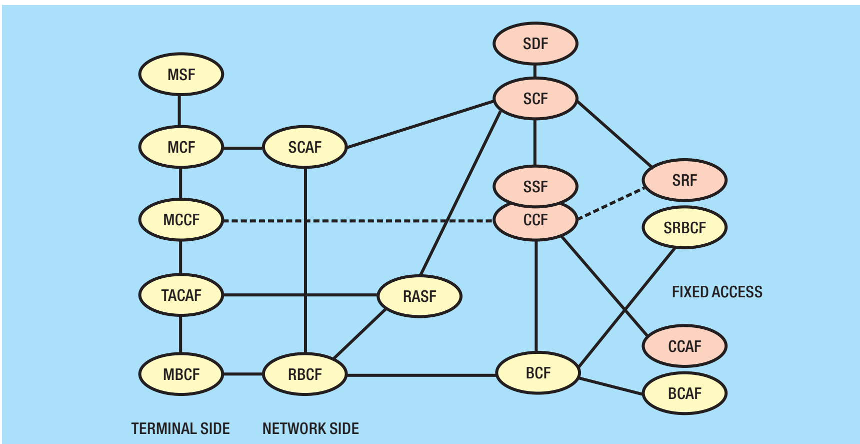
In the last decade, many PCS systems supporting a variety of services have evolved to the existing wireless networks (second generation) as Figure 2 shows. These networks are characterised by relatively narrow bandwidth and considerable limitations regarding their interworking. In order to overcome these problems and to establish a universal personal wireless and multimedia communication system, the third generation of mobile telecommunications systems is currently under development.

The universal mobile telecommunication system (UMTS), developed by the European Telecommunications Standards Institute (ETSI), and International Mobile Telecommunications by the year 2000 (IMT2000), developed by the International Telecommunications Union, which are the main representatives of this generation, are scheduled to start service around 2000–2005 and provide a range of telecommunications services to mobile and stationary users in a variety of environments. UMTS/IMT2000 will support terminal, personal and service mobility, and thus will allow person-to-person calling independent of location, terminal used, means of transmission (wired or wireless), and choice of technology. In UMTS and IMT2000, PCS (including high bit-rate data and audiovisual services) will be based on a combination of fixed and wireless/mobile services to create seamless end-to-end services for the user.

UMTS/IMT2000 will be coupled with IN to develop and deploy PCS, following the paradigm of the customised applications for mobile network enhanced logic (CAMEL) environment, which has been introduced into the GSM system to utilise IN technology and support services not covered by standardised GSM. In that sense, new functional entities have been added to the IN functional model, as can be seen in Figure 3, to deal with specific UMTS requirements. These are the mobile storage function (MSF), mobile control function (MCF), mobile call control function (MCCF), terminal access control agent function (TACAF), mobile bearer control function (MBCF), service control agent function (SCAF), radio bearer control function (RBCF), radio access control function (RACF), bearer control function (BCF), specialised resource bearer control function (SRBCF), and bearer control agent function (BCAF). These functional entities are added to provide the necessary mobility and interworking functions, and to carry out the service related processing.

This enriched UMTS/IMT2000 system will eventually lead to a virtual home environment (VHE), which is defined as a system concept for personalised service portability across network boundaries and between terminals[8]. VHE is provided by a service provider according to a subscription (that could involve more than one user) over different terminals and network operators. However, VHE will enable users to receive services with the same feel and look as they roam across different networks. In general, VHE aims to provide users with personalised services, a personalised user interface, a consistent set of services irrespective of access (fixed, wireless), and global service availability when roaming. The achievement of this goal depends on the cooperation and relative capabilities of home and

Figure 3—Extended IN functional model for UMTS



visited networks, as well as the relative capabilities and compatibility of the used terminals[26].

Currently, most VHE approaches are heavily based on IN technology. However, IN does not provide a homogeneous programming environment to allow interworking and portability of system components, and IN infrastructure depends on the technology used by operators for implementation. To overcome such IN limitations, and to facilitate the implementation of the VHE concept in a more flexible, efficient, and effective way, the application of TINA-C is proposed[7].

This would require a modification of the TINA-C architecture to fully support mobility functions. Such an effort has already been undertaken by several European Union research projects. Among them, DOLMEN has provided a number of TINA-C extensions in the area of mobility, validated these extensions through an international field trial, and highlighted a number of important open issues that will be the target of further research in this area[27]. However, irrespective of the outcome of future TINA-C specific research regarding the VHE, integration with the VHE standardisation efforts that are currently on going is necessary.

Conclusions

Existing telecommunications systems are gradually converging into a ubiquitous information infrastructure inside an open deregulated multi-provider telecommunications marketplace. Additionally, the demand for telecommunications services is increasing and will increase rapidly in the years to come. Based on these assumptions, this paper has outlined and examined what appears to be some major factors and technologies to be considered in deriving a viable paradigm for the broadband information highway of the future.

The TINA-C architectural framework is gradually maturing and gaining acceptance at a constant rate, through validation activities and the examination of interworking concepts and migration strategies from existing technologies. For this reason, it is envisaged that TINA-C will provide universal programmable connectivity between mobile users supporting a variety of mobile services (cordless, cellular, paging, mobile satellite) in the framework of the universal broadband mobile telecommunication system (UBMTS) that will emerge as the result of the activities pertaining to the fourth generation of mobile systems. In that way fixed and mobile networks will eventually converge enabling the realisation of a VHE[7, 27].

Furthermore, the state of the Internet and its evolution is also a crucial matter for the future, whether it is going to be considered as the universal paradigm for the truly global information infrastructure, or as something destined to evolve naturally from its present state to be one of the elements of the overall telecommunications scenario.

To effectively answer the technological challenges of future telecommunications environments and to provide both fair competition and regulated liberalisation, standardisation is necessary[15]. The essential objectives of standardisation relate to interconnectivity and interoperability. Joint activities have to address suitable reference architectures, functional models, well-conceived building blocks, open interfaces and protocols, and appropriate migration scenarios, without restricting the needs and creativity of the different parties/countries involved. Balance is also required between innovation and coordination taking into consideration dynamic developments in regulation, markets, and technologies.

For the transfer towards the information society, many political and legal problems have still to be solved both on a national and international basis, in addition to technical and economical aspects. These problems relate to setting up an appropriate and stable regulation for competition, providing faster progress, greater choice, higher performance, and lower costs and to institute a suitable legislation for the content, addressing among others, intellectual property rights, security and privacy, and the timely and accurate publication of interface specifications[24]. The process of facing these issues requires common vision, harmonisation, joint action, and above all a careful balance between cooperation and competition.

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Prof. George Pavlou received his Diploma in Electrical and Mechanical Engineering from the National Technical University of Athens, and his M.Sc. and Ph.D. in Computer Science, both from University College London. Over the past 12 years he has been undertaking and directing research in the areas of data communications and telecommunications with emphasis on performance evaluation, network and service control and management and the use of distributed object-oriented technologies in new telecommunications architectures. He has contributed to ISO, ITU-T, NMF/TMF, OMG and TINA standardisation work. He has published around 50 papers in international refereed conferences and journals and he is the co-author of two books. He is currently professor of information networking at the University of Surrey, School of Electrical Engineering and Information Technology, where he leads the activities of the networks research group.

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