Support for Moving Users through Thin Clients: Hype or Future?

Matthias Strobbe, Pieter Simoens, Lien Deboosere,
Davy De Winter, Frederic Van Quickenborne, Filip De Greve,
Filip De Turck, Bart Dhoedt, Piet Demeester
Ghent University - IBBT - IMEC
Department of Information Technology
Gaston Crommenlaan 8, bus 201
9050 Gent, Belgium
Email: matthias.strobbe@intec.ugent.be

Abstract- **Nomadic and mobile users are highly interested in lightweight devices with low energy consumption that are still able to execute their regular applications. When applications are executed on remote servers instead of locally on the end-user's device, the weight of the device can be reduced and battery lifetime can be extended. Therefore, thin-clients are ideally suited for mobile users. These devices communicate with an application that executes the commands, renders the appropriate screen updates and returns to the client. To enable ubiquitous thin-client computing with satisfying user responsiveness, the application should make a parallel movement with the mobile user. In this paper we present an architecture that acquires and aggregates context information from the user and the network - such as the locations of the users, the state of the network, user preferences, etc. - to determine an optimal process migration strategy.**

Keywords: Thin Clients, Mobility, Context Awareness

I. Introduction

Mobility has become commonplace in today's networks. Nomadic and mobile users are highly interested in light and easyto-transport devices that are still able to execute their regular applications. The fundamental requirements for these devices are the dimension, weight and battery lifetime. To optimize these we see an evolution towards a removal of as much as possible functionality and hardware, not related to input and output. All calculation logic is removed from the device and the communication with the application server is accomplished by a remote desktop protocol. By removing all processing hardware, the device can be made lighter and performing the complex calculations on network servers instead of locally on the end-user's device decreases energy consumption and extends the battery lifetime.

Reactions to user events can appear on the screen only after a two-way path delay, so application responsiveness can decrease if the user moves further away from his server. To guarantee a high overall user experience, the delay should be as low as possible. This can be accomplished if the interactive services travel through the network and migrate to the closest available application server.

To control the handovers between two application servers, an overlay management platform is needed. This control framework will assign a server to new applications. Existing connections are monitored to guarantee the desired user experience. If the quality drops below predefined thresholds, a better application server must be found. The user session is migrated towards this new server and restarted. All of this should happen without the user noticing, or at least with a minimal down-time to the user's applications.

To make an optimal decision the control framework has to take context information from the user and the network into account. Of key importance is of course tracking or predicting the location of a user, but also user preferences, type of service subscription and network aspects (processing power, available bandwidth), will determine the optimal process migration strategy. To make a good decision all relevant context information has to be easy available, so gathering of context information from several sources is needed. Moreover this information should be modelled according to a formal model allowing validation, derivation of extra information by reasoning and easy exchange of the information.

In this paper an overview of the state of the art will be given of key technologies facilitating the construction of an adaptive context-aware service platform. First a use case in a train environment will be presented (section II) and an overall architecture to support mobile users by taking context information into account (section III). Next, the different key technologies will be discussed in more detail. This comprises thin clients (section IV), connectivity provisioning (section V) and context awareness (section VI). Finally we state our conclusions (section VII).

II. Use Case: Thin-clients in Train Environment

An environment where thin clients can be very useful is a train environment. Commuters on their way to their work or on the way back want to spend their time efficiently by carrying out some work (e.g. sending e-mails, prepare documents, even videoconferencing), so they have more time at the office for other things. Or they want to relax themselves by listening to music, watching videos or playing games. So they need access to their personal files and their regular applications via the network. To keep the delay low, the applications should

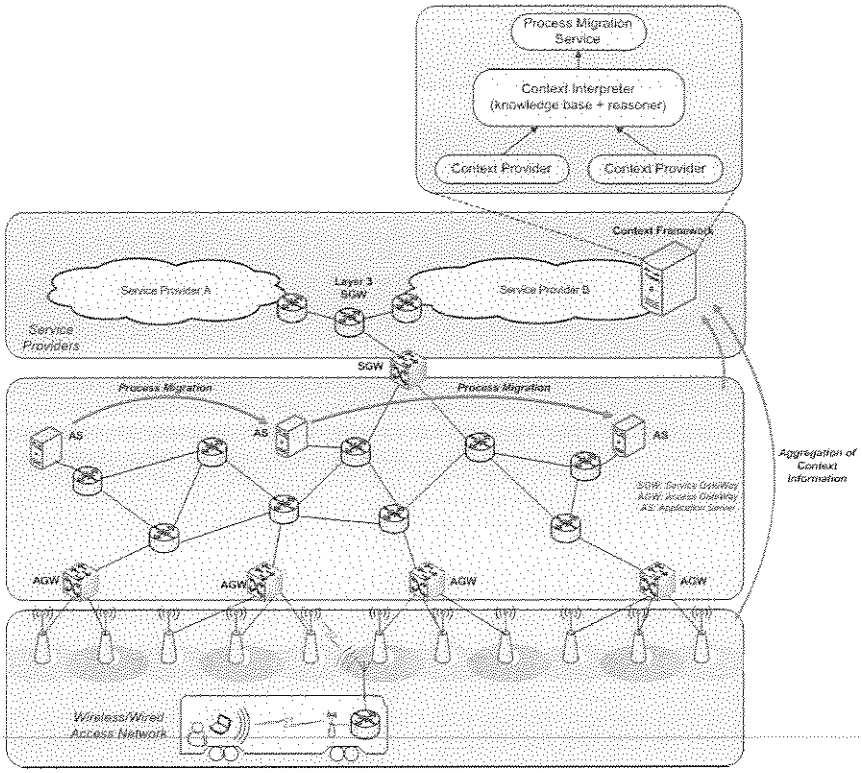

Figure 1. Overall system architecture to support mobile users based on context information

travel through the network and reside on a server close to the user. To determine the location of the user, the heart beat mechanism of the train or GPS could be used. As possible many users on the train want to make use of such services the delay cannot be minimal for all of them, as the available bandwidth and processing power in the network are limited. To determine the optimal process migration strategy over all users it is important to take other context information into account next to location, like network characteristics, user preferences and the type of service description of the different users.

III. Architecture

Fig. 1 gives an overview of the proposed architecture and illustrates the use case. Commuters on the train are connected to the internal WiFi train network and the train carriages are connected to the closest wireless base station near the railroad track. The connection with the aggregation network is realized via Access Gateways. In this aggregation network application servers are geographically distributed to support the thin clients of the mobile users. To determine the optimal process migration strategy context information is gathered and aggregated in a context framework running at a service provider.

The most important kind of context information is the location of the users. As said before the heart beat mechanism of the train or GPS could be used to capture this information. Next to location information, information about the state of the network and the application servers is needed. As the capacity of the links of the network and the processing power of the application servers are limited, the current demand has to be monitored to determine an optimal distribution of the applications over the server farm. If possible also the demand in the near future should be predicted. When choices have to be made like which users get the lowest delay, information about the users becomes useful. Important here is the service subscription. The more you pay the better your overall user experience. But also user preferences are taken into account. For some users a low delay may be more important than a packet that get lost once in a while, while other users may find a reliable connection more important. Of course also the type of application will make a difference. When playing a game on a central server, the impact of a key stroke must be immediately visible on the screen, whereas other applications do not suffer from a small delay.

This gathered context information is represented in a formal way according to an ontology-based context model. This allows validation of the information and deduction of extra implicit information, permitting the Process Migration Service to take intelligent decisions.

IV. Thin-Clients

A. *Thin-client protocol*

In a typical thin-client system, an application is executed on a server. The communication between the client and the server is based on a remote display protocol, for example VNC (Virtual Network Computing) [1]. Keystrokes and other user-events are sent over the network to the server. The server renders the appropriate video-updates for the client and sends these to the client. The client only has to decode and show the videoupdates on its screen.

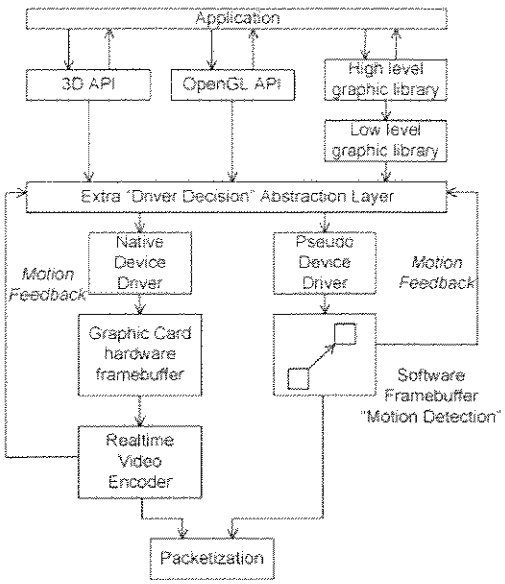

Figure 2. Hybrid thin-client protocol at the server side

Most thin-client protocols were developed for use in LAN environments and perform poorly in WAN environments [2]. The quality of a high-motion multimedia session on a widearea thin-client, is lamentably poor due the high rate of screen updates. In [3], an in-house developed hybrid thin-client protocol for desktop-, multimedia- and 3D Game-applications is presented. Instead of using a classic thin-client protocol for all applications, a realtime desktop streaming protocol is used for high-motion scenarios. This approach improves the quality of the user's multimedia session on his thin-client. Fig. 2 represents a possible implementation of the hybrid thin-client protocol at the server-side. An extra abstraction layer is inserted between the graphical libraries and the driverlevel. Depending on the amount of motion in an application, video-streaming or a classic thin-client protocol will be used to send the graphical output of an application to a thin-client. The requirement for GPU-acceleration can also be used as a criterium.

By moving away the application logic from the client's device to application servers in the network, the simple client's device does not need complex hardware components. That way, energy-consumption can be reduced significantly and thus the battery-lifetime can be extended. In table I, the energy consumption of different thin-client protocols and our streaming solution are compared with local execution of the application. The results are somewhat misleading, as streaming seems to consume much more energy than the other approaches. If we take the quality of the session and bandwidth overhead into account [3], streaming outperforms the other solutions. In the OpenOffice scenario, remote execution (FreeNX) consumes 0.77 Watt more energy than local execution, caused by the constant WiFi energy-overhead. If future WiFi chips consume less energy with lower bandwidths, the energy consumption will be able to equal that of local execution. In the other scenarios, remote execution consumes less energy than local execution. A non-optimized software decoder was used, but from [4] we can conclude a hardware video decoder can be made up to 10 times as energy-efficient as an optimized software solution. We expect to see in future implementations a really significant energy reduction of the high-quality streaming solution.

	FreeNX	TightVNC	X11	STREAM	LOCAL
OpenOffice	2.44	2.64	2.59	16.98	1.67
Browsing	2.53	2.94	3.43	17.47	7.01
MPlayer	10.67	5.45	2.68	17.81	18.05
Gaming	-	-	-	19,47	25,13

Table 1. Comparison of Energy Consumption (Watt) for Remote and Local Execution

B. Process migration

Since reactions to user events can only appear on the screen after a two-way path delay, users of thin-clients in a widearea environment could suffer from a high latency when the same application server is used at all times. The application should always be executed on a server able to guarantee delay constraints are fulfilled. This means the server executing the application for a user, depends on the user's current location. As users travel around the world, their applications should make a parallel movement in order to keep the end-to-end delay below a predefined threshold.

Process migration is a technique that takes a snapshot, called a checkpoint, of the current state of the application. It then moves this checkpoint from one server to another and finally restarts the application in exactly the same state as before. Fig. 3 gives an example. At t = 0 the user's application is executed on a server nearby his access gateway (AGW). At t = 1, the user has moved and is now connected to another access gateway, but the same server can still fulfil the quality requirements of the user. When the user moves further, this is no longer valid and at t = 2, another server will take over the job. The application of the user migrates to the new server, where it is restarted in exactly the same state as before. At t = 3, the user reaches his destination. His application is

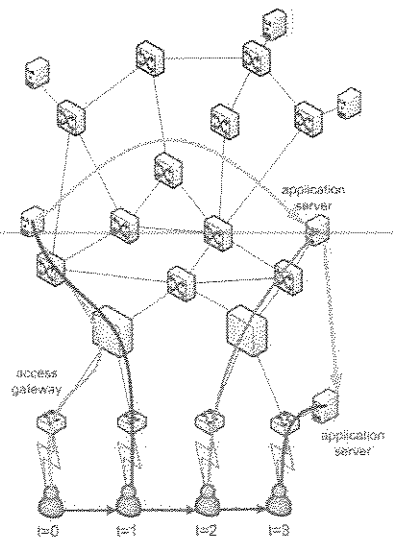

Figure 3. The application migrates along with the mobile user to the closest available application server to guarantee an acceptable delay at all times.

migrated and restarted at the application server of the company he works for to reduce the load on the network.

A lot of research has been done on process migration. Older migration systems, e.g. Condor [5], were developed for load balancing in a server farm. More recently, ZAP [6], a transparent process migration technique was introduced by the Columbia University, NY. In ZAP, a virtualisation layer is inserted above the operating system. This allows to fully migrate an application, including open network connections, open files etc., without leaving any residual state at the original server after the migration.

To enable process migration, a good geographical distribution of servers is crucial. In [7] a theoretical model to determine where to install servers in a given network and how many is presented. In [8], three mechanisms to perform a seamless handover between application servers are proposed. Focus is on how to minimize the downtime while sending the checkpoint from the original server to the new server.

V. Network Connectivity

With the currently emerging trials for internet solutions on the train, it is a matter of time before best-effort internet on the train becomes a reality. However, the challenge current telecom operators are facing is to deliver multimedia applications such as content delivery, video phoning and on-line gaming - which are generally characterized by high bandwidth and low latencies requirements - to users in fast moving vehicles. There is no consensus on a widely deployed platform but candidate wireless technologies are: cellular techniques, satellite based solutions and Wifi/WiMax-based solutions. Currently, a lot of trials are deploying hybrid solutions in order to have maximal coverage: e.g. WiFi access when the vehicle is in the vicinity of a hotspot and GPRS access throughout the rest of the trip. While satellite-based solutions are still the dominant player in the Internet-on-the-train business, on-roof antenna architectures with WiFi/WiMax base stations located near the railroad track are recently gaining a lot of interest. In [9] a network architecture based on track-side antennas is presented. This solution enables a real-time seamless broadband service in small cell infrastructures (i.e. micro-cellular networks) due to the ability to offer higher bandwidths and lower end-to-end delays. This requires dense installation of wireless base stations along the railroad track which need to transport the traffic from the vehicles to the fixed networks of service providers.

The network architecture is represented in Fig. 4. While the train passengers are connected to the internal WiFi train network via an on-board wireless router, the train carriages remain connected to the closest wireless base station near the railroad track. Base stations are grouped in access networks and the connections between access networks and the aggregation network are realized via Access Gateways (AGWs). At the other end, the aggregation network is connected to the service providers' networks with Service Gateways (SGWs). The aggregation network itself is responsible for the reliable

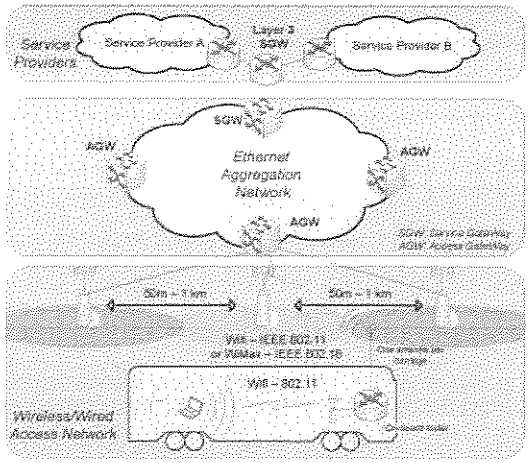

Figure 4. Schematic representation of the network architecture - specifically designed to cope with the requirements of train passengers.

transport of data between AGWs and SGWs. However, current fixed aggregation networks are not optimally designed to cope with fast moving users and no mechanism is supported to maintain QoS guarantees for the admitted connections during the entire journey of the moving users. Therefore, an advanced dynamic traffic engineering problem has to be examined which can be described as follows: how to set up a dynamic path between the gateways in an aggregation network to meet the traffic demand of a request while achieving low congestion and optimizing the utilization of the network resources. The connectivity in the aggregation network is achieved by setting up dynamic Layer 2 tunnels in the aggregation network between the AGWs and the SGW in which the aggregated traffic flows are mapped. Service guarantees can be assured by making on-time resource reservations. When reservations are no longer required, they are immediately released. Because trains will use a heart beat mechanism to indicate their current point of attachment, the SGW is constantly updated with information about the current (and future) positions of the trains. More detailed location information such as GPS information could be used on top of this to determine the optimal handoff moment. On top of this Layer 2 architecture, Mobile IP can be deployed in order to enable handovers between different Ethernet domains.

VI. Context Awareness

Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and application themselves [10]. It can be anything: location information, environment factors as weather, temperature, time, traffic, user preferences, etc. but also information (e.g. the mood or activity of individuals) that can only be derived by intelligent combination of other context information, or by human inputs. A context-aware system uses context information to automatically adapt services

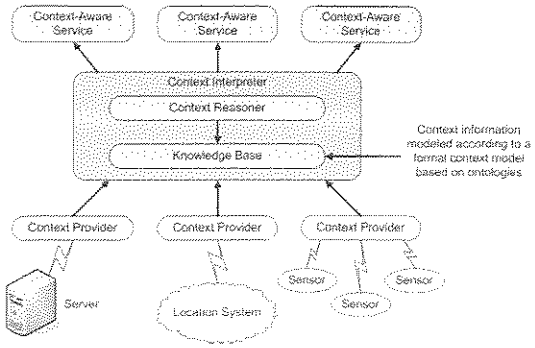

Figure 5. Schematic representation of a component based context framework architecture.

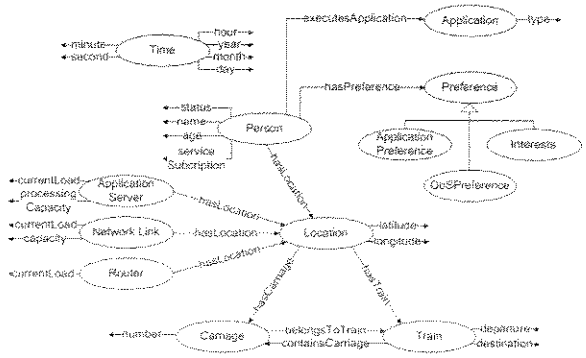

Figure 6. Example ontology for the use case in a train environment

and to provide relevant information and/or services to the user.

Research on context-aware applications started about 10-15 years ago and since then we can distinguish 3 phases in the development of such applications. In a first phase we had a strong coupling between the actual applications and the sensors that gathered the specific context information. In a second phase a component based framework was defined for the development of context-aware applications [10]. In a third phase, a common context model was added, e.g. based on ontologies. Examples are SOCAM (Service Oriented Context Aware Middleware [11]) and our own framework [12].

Fig. 5 shows a schematic representation of our component based framework. The framework has two important functions: aggregation of context information and reasoning on the obtained information to validate the information and to derive new implicit information. The context providers take care of the acquisition of the several types of context information. As the framework is component based it is easy to add or remove components that deliver specific kinds of context information (e.g. a location provider, a user preference provider, etc.). To derive high-level implicit information (by the context interpreter) all context information is aggregated in a knowledge base and represented in a formal way, according to a common context model.

Typically, ontologies are used to define such a context model. These are formal descriptions of concepts in a particular domain. They provide a vocabulary for representing knowledge about a domain and for describing specific situations in a domain. By using ontologies, context can be described semantically independent of programming language, underlying operating system or middleware. Moreover they allow formal analysis and interpretation of domain knowledge. The most used language to describe ontologies is OWL (Web Ontology Language [13]) defined by W3C. OWL is an XMLbased language that allows an accurate description of domain knowledge with classification, modelling of dependencies and restrictions on these dependencies. It allows reasoning and other ontologies can be imported, encouraging reuse and improving scalability.

Referring back to the use case, figure 6 gives an example of a possible ontology. A user is modelled, with some personal information, his preferences, the applications he is currently executing and his location on the train. Also the different components of the network (routers, links and application servers) are modelled. Important for these components is their location, as the Process Migration Service will need that information for its migration strategy. As on different moments of the day, typically different types of applications will be executed, also the current time is modelled. The services use the context information of the knowledge base to adapt themselves to the current context and to take intelligent decisions. So for our use case, the Process Migration Service will use the information of the knowledge base to migrate the different applications as optimal as possible.

VII. Conclusion

In this paper an overview of the state of the art was given of key technologies facilitating the construction of an adaptive context-aware service platform. A use case in a train environment was presented together with an overall architecture to support mobile users based on context information. Then, the key technologies were discussed in more detail: thin-clients with focus on protocols and process migration, connectivity provisioning for fast-moving vehicles and context-awareness with focus on aggregation, representation and reasoning on the context information.

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AUTHORS

MATTHIAS STROBBE received his M. Sc. degree in Computer Science Engineering from the Ghent University, Belgium, in July 2004. He is now a research assistant and Ph.D student affiliated with the Department of Information Technology of the Ghent University. His main research interests include interactive digital television, software architectures for support of context awareness and location based services.

PIETER SIMOENS received his M. Sc. degree in Electronic Engineering from the Ghent University, Belgium, in July 2005. Since October 2005, he is research assistant with the Fund for Scientific-Research-Flanders, Belgium (F.W.O.-V.) affiliated with the Department of Information Techology of the Ghent University. His main research interest is the development of a network architecture for thin-client computing.

LIEN DEBOOSERE received her M. Sc. degree in Computer Science Engineering from the Ghent University, Belgium, in July 2005. She is now a Ph.D. student affiliated with the Department of Information Technology of the Ghent University. Her main research interest is the development of a network architecture for thin-client computing.

DAVY DE WINTER received his M. Sc. degree in Computer Science from the Ghent University, Belgium, in July 2003. He is now research assistant and Ph.D. student affiliated with the Department of Industrial Sciences of the Hogeschool Gent. His main research interests are the study of thin-client protocols and architectures, and content-distribution techniques.

FREDERIC VAN QUICKENBORNE (M. Sc. Degree in Electrotechnical Engineering, University of Ghent, Belgium, 2002) published different papers on the growing importance of ethernet in aggregation and core networks. Besides his interest in ethernet related topics (QoS, VLANs, xSTP), he is also involved in projects concerning video-streaming and is working on a Click-based ethernet testbed. This research is funded by a PhD grant from the Institute for the Promotion of Innovation through Science and Technology in Flanders (IWTVlaanderen), that he obtained in 2004.

FILIP DE GREVE was born in Gent, Belgium, in 1978. He received his Master of Science degree in Electrotechnical Engineering from Ghent University, Gent, Belgium in 2001. In 2002, he joined the Department of Information Technology of the Faculty of Applied Sciences, University of Ghent as a doctoral researcher. Besides specific Ethernet-related research topics, his current research interests are related to broadband communication networks and include design, routing and reliability of access and aggregation networks.

FILIP DE TURCK received his M.Sc. degree in Electronic Engineering from the Ghent University, Belgium, in June 1997. In May 2002, he obtained the Ph.D. degree in Electronic Engineering from the same university. From October 1997 to September 2001, Filip De Turck was research assistant with the Fund for Scientific Research-Flanders, Belgium (F.W.O.-V.). At the moment, he is a part-time professor and a postdoctoral fellow of the F.W.O.-V., affiliated with the Department of Information Technology of the Ghent University. Filip De Turck is author or co-author of approximately 80 papers published in international journals or in the proceedings of international conferences. His main research interests include scalable software architectures for telecommunication network and service management, performance evaluation and optimization of routing, admission control and traffic management in telecommunication systems.

BART DHOEDT received a degree in Engineering from the Ghent University in 1990. In September 1990, he joined the Department of Information Technology of the Faculty of Applied Sciences, University of Ghent. His research, addressing the use of micro-optics to realize parallel free space optical interconnects, resulted in a PhD degree in 1995. After a 2 year post-doc in opto-electronics, he became professor at the Faculty of Applied Sciences, Department of Information Technology. Since then, he is responsible for several courses on algorithms, programming and software development. His research interests are software engineering and mobile & wireless communications. Bart Dhoedt is author or co-author of approximately 100 papers published in international journals or in the proceedings of international conferences. His current research addresses software technologies for communication networks, peer-to-peer networks, mobile networks and active networks.

PIET DEMEESTER received the Masters degree in Electrotechnical engineering and the Ph.D degree from the

Ghent University, Gent, Belgium in 1984 and 1988, respectively. In 1992 he started a new research activity on broadband communication networks resulting in the IBCN-group (INTEC Broadband communications network research group). Since 1993 he became professor at the Ghent University where he is responsible for the research and education on communication networks. The research activities cover various communication networks (IP, ATM, SDH, WDM, access, active, mobile), including network planning, network and service management, telecom software, internetworking, network protocols for QoS support, etc. Piet Demeester is author of more than 400 publications in the area of network design, optimization and management. He is member of the editorial board of several international journals and has been member of several technical program committees (ECOC, OFC, DRCN, ICCCN, IZS, &).

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FITCE.BE Young ICT Professional 2007 → 2008

If you are young and looking for the next challenge in your professional career then you should have a close look at the following. '*The Media and Communications Industry Anno 2015*' is the theme of the competition for *'FITCE.BE Young ICT Professional 2008'*. Young ICT people interested in joining this contest can find the rules of the game here, and are requested to register no later than <date to be defined>. One of them will become the successor of last year's winner, Steven Van

den Berghe.

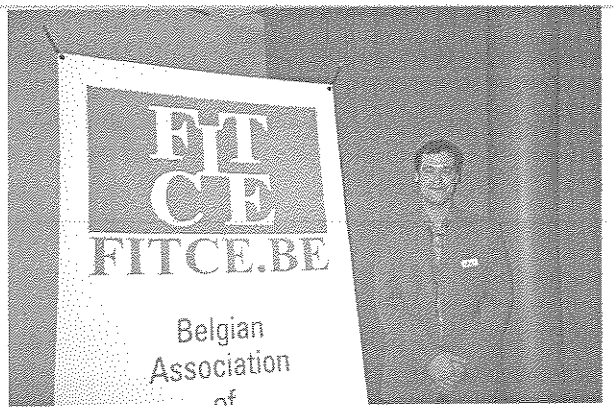
Here is what Steven has to say about what it meant to him to participate and win the contest. Read also his views on the engineering profession and ICT. This is why more young people should get into engineering.

What did it mean to you to win the 'FITCE.BE Young ICT Personality 2006' competition?
Winning the competition was of course the greatest personal achievement in my professional life so far. But even my participation as such, and especially the ability to present my vision in my own way in the finals, to public with a broad range of ICT (and even non-ICT) backgrounds was already one of the most interesting things I have done in my young ICT carreer.

Why did you choose to become an engineer?
I've always been, and still am, interested in a wide range of subjects. And engineering is the place where "everything comes together". It's the place where mathematics meets biology, economics meets logic, and probably hundreds of other domains intersect when "trying to build a solution". And even though I have been focussing on a single domain (telecom) in the last seven years, I still encounter all these things while programming, finding heuristic algorithms, performing network simulations and so on.

What is so great about this profession?
In a single word: challenges. I get up every morning knowing that new problems will need to be solved, products can be "invented" and already knowing in advance that the next day will bring even more and new challenges. So there is no room to get bored with it.

And more in particular, what is so exceptional about ICT?
A lot of people will probably answer "the fact that it progresses so quickly" to this question. Well, I tend to disagree. For me we have always been, and still are, simply adding up registers in a CPU, storing data on a disk and sending packets over the network. The exceptional part is what we can build by integrating these simple components. It is amazing how we can continue to combine simple computations, data and packets over a wire to achieve new exceptional solutions such as interactive digital television and eHealth services.



Mr. Jan Deprest then addressed the Belgian situation and the government's efforts at bridging the digital divide. He highlighted the two main focuses of Fedict , the young Ministry of ICT, which are e-government and e-society. When the first deals with upgrading the services of the government to the citizen through ICT, the second deals with making available the benefits of ICT to all of the population. In the remainder of his spirited speech, Mr. Deprest gave an overview of the many initiatives of Fedict in the area of e-society such as 'Internet for All'. Read more in Mr. Deprest's presentation.

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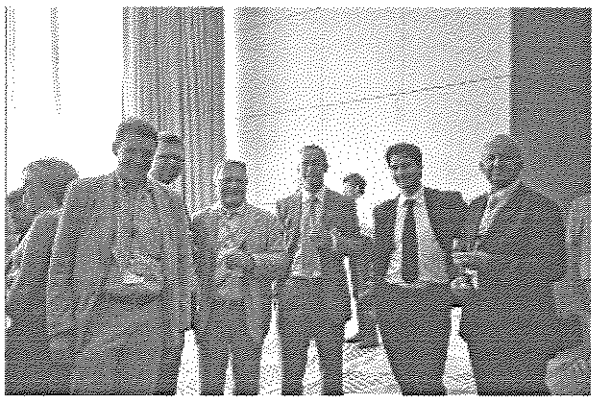
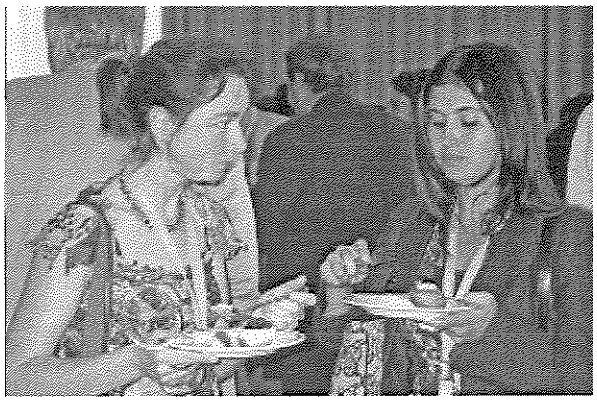
The FITCE Congress in Athens

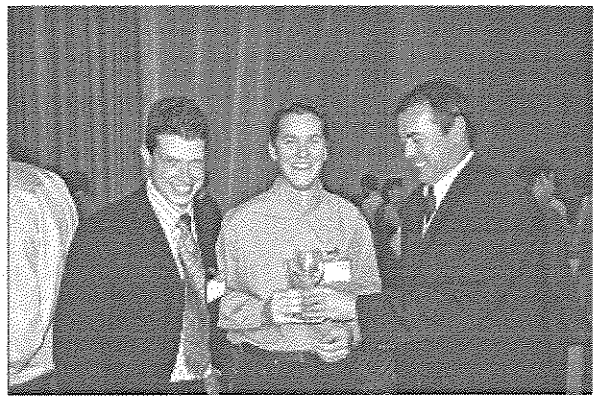
EU Commissioner Viviane Reding, Information Society and Media, was the key speaker at FITCE's 45th European Telecommunications Congress. The congress with as motto 'Telecom Wars: the Return of the Profit' was held in Athens from 30 August to 3 September, 2006. The Belgian delegation consisted of 29 people, including accompanying persons. On a total of 279 participants, this was the largest delegation after the Greek one.

>Opening Session and Reception<



After the opening session, the reception is the opportunity for friends to meet again while some of the presenters are getting their first flavour of a FITCE congress. On the left bottom picture, Peggy Valcke and Eleni Kosta, both from ICRI at KU Leuven, Bottom right picture shows Marc Verbruggen toasting with Raf Meersman and Koert Vlaeminck.

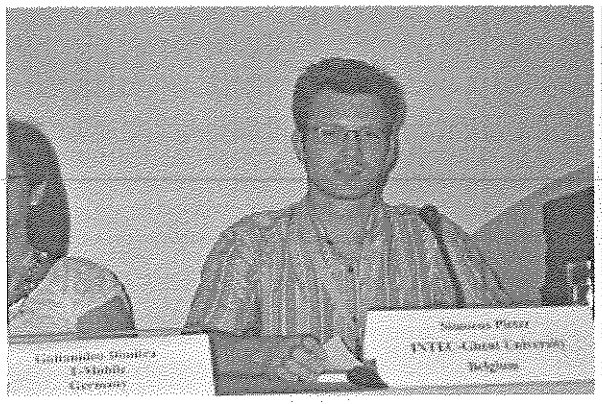




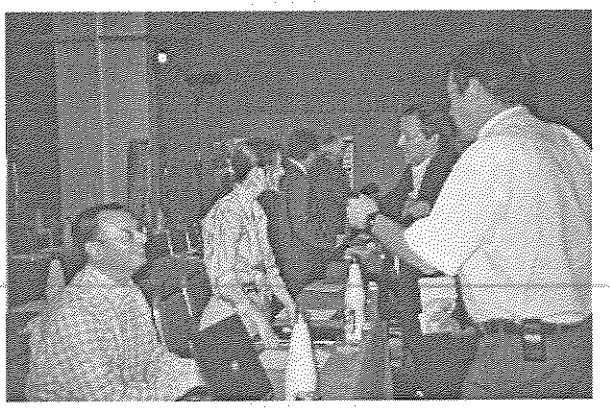
>Technical Sessions<

No less than eight paper proposals from Belgium had been accepted by the international scientific committee in which our national association was represented by Marc Verbruggen, member of the board. One additional Belgian paper was presented on behalf of sponsor Alcatel. Also, the winner of this year's contest 'FITCE.BE Young ICT Personality of the Year', whose prize was participation in the congress, presented his winning paper. FITCE Belgium thus had a very strong representation in this congress which was once again of high quality both by the intrinsic value of the presentations and presenters but also by the diversity of the subjects.


Above left, Marc Verbruggen, session chairman, opens the session on 'How to converge'. Above right, Raf Meersman and Jan Van Ooteghem waiting for their turn to take the floor for a joint presentation.




Above left, Pieter Simoens getting ready for his speech. Above right from the left, Peggy Valcke together with Veerle Van Rompaey and Bart Van Der Meerssche looking ahead with justified confidence to yet another excellent performance. Below, Roland Thienpont on the left getting some last minute good words from Marc Verbruggen.



Below left, Eleni Kosta delivering the presentation with which she won the 'Best Young Presenter' award. Below right, Carine Neus at the presenters' table during her session.