An Interview with

ANDRE DANTHINE

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Abstract

In this interview, André Danthine describes his career in computer networking. He describes his education and introduction to computer networking in Belgium and the United States in the early 1970s, as well as his participation in European and international networking projects such as OSI, ESPRIT, COST 11, and IFIP. He reflects on the introduction of packet-switched networking in Belgium, and on the future of Internet protocols.

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Russell: Today is April 6th, 2012. I'm here with Professor André Danthine at the University of Liège to talk about his career in computer networking. My first question is a very general question about your education. Can you please describe your education and your first experiences with computers?

Danthine: My education is an education of a civil engineer. Five years of study here at the Liège University, which was composed of two years of basic training in chemistry, physics, and mathematics for all the engineering diplomas. And after that, I got into three years of electrical and mechanical engineering because at that time no computer engineering was already offered.
After that, I stayed one year as assistant with the Montefiore Institute of the University. This Institute is very old. It has been funded through a donation from a visionary – Mr. Montefiore – who attended the 1878 World Fair in Paris where he saw the Gramme dynamo. And as he was an industrialist, who was working with a lot of machines driven by belts and distribution of power from steam engines, he was immediately convinced that electricity would be very important because he would be able to distribute his machines freely and change the place of equipments to build a more flexible environment for producing his goods.

His was one of the 12 most important fortunes in Belgium. And he made a donation of 100,000 gold francs to the University to create in 1883 an institute of electricity. He funded the building and the Chairs. Three years later, he funded the association of Electrical Engineers graduated from the Institute.

During my stay as an assistant, I applied for a grant from the B.A.E.F. – Belgian and American Education Foundation. I was fortunate to get one. And I decided to make a Master's at MIT. At that

time, my specialty was automatic control. I worked for my thesis on a part of the guidance system of a missile. MIT has a deep relationship with the US Navy. Many laboratories, research programs, researchers and graduate students are partially or totally funded by the Navy. On the Navy day, most of my classmates were not anymore informal in dressing and behavior but were in parade uniform in a very rigid attitude. And so after my graduation, I came back to the university.

Russell: What year were you at MIT?

Danthine: At the electrical engineering department, in 1959-1960. Then I came back here. My intent was to create at the Institute a department of automatic control, which was missing in the curriculum of the electrical and mechanical engineers. My professor at that time was supporting me very much. My position was clear. I was waiting for a commitment of the University to create this department, this area of teaching and research, or I would leave because I did not want to spend years at the university just waiting. And finally at that time, in 1961 there was no money available and they cannot make any promise to me. And I decided to leave.

I was in contact at this moment with the Battelle Institute in Geneva, very close to being hired. But it was a vacation time. Some delay came. And at the same time, the Center of Metallurgical Research for Benelux, which is located in Liège, was looking for someone that would be able to take the head of a project with CECA, the European Coal and Steel Community, in order to attack the problem of the blooming mill automation, rolling mill automation. It is the first step of the manufacturing of the steel from the furnace, you know? I was waiting for a contract on one side and I got a second offer on the other side. When you are very close to the deadline, you have to make a choice. I chose the

blooming mill automaton project, and two weeks after, I got the contract from the Batelle Institute but it was too late. So decisions in life are done without any regret, just by chance, by *hasard*.

This research lasted five years and was successful. At that time, everything which was electronically driven was driven with program logic. No flexibility. No programming, not in the sense of what we know. And we introduced for the first time the idea of a process computer in this installation. It was successful. During the five years of this research I did some theoretical research on optimization. I made one of the first applications of the Pontryagin Maximum Principle for the optimization of the rolling mill process. This approach was used before in the optimization of supersonic aircraft trajectory by A. E. Bryson, known as the "father of modern optimal control theory." I had the opportunity to apply also the Pontryagin Maximum Principle in France to optimize the energy to roll a difficult steel to process, the stainless steel (this steel does not rust). A gain of 15% of energy was achieved by the dynamic characteristics of each step of the unmodified rolling sequence.

In 1966, the University had finally decided that they would create an automatic control department. So they opened a new Chair. And as I was at the end of my CECA project, I applied with the full support of the Center of Research for the Metallurgy and the Steel industry. In 1967, I was nominated for the new chair, with tenure. The two first years have been used to develop my lectures and to prepare my future activities. I wanted to continue to do theoretical research but I wanted also to have projects in connection with practical problems. But in the search of projects, I did not wanted to enter in competition with the Center of Research in Metallurgy. In 1970, I learned through [an] IEEE publication about ARPAnet based on a packet switching technology introduced by Paul Baran. Universities and Research Centers are interconnected through small computers called IMP, Interface

Message Processors, (ancestors of routers) supporting data transmission by packet switching on a physical link at 50 Kbps. Each host is connected to one IMP. Each IMP is a node of the network. It is implemented in a Honeywell computer taking 2 units in a 19-inch rack. Before Arpanet, the access to a host required a specific terminal with a direct connection. The first motivation for Arpanet was to be able, with a single terminal, to access all the hosts of the network.

In 1971, I was invited at Illinois University to make a presentation of my application of the Pontryagin Maximum Principle for the rolling mills. As Illinois was a node of Arpanet, I accepted the invitation of my colleague of Automatic Control department. I was very excited to have the possibility to see this node, to see how it works and if it was useful or not. So after my conference, I asked to see the device, but my colleague did not know anything about this IMP. At the computer center, they knew that there was a device but nobody was able to [say] where it was. On the day of my departure, the very day of my departure, I had a plane to take around noon. I got a call at 7:00 saying, “We have the guy you need to see the box you want.” The guy was on vacation. Where did we find this box? In a passage in a big closet. Below were all the cleaning equipments and on a self on the top, the IMP, the node. The guy told me, “Okay. Yes, it works. And what do you do? “Ah, we do nothing. The node is entirely controlled by Bolt Beranek and Newman, BBN, from Boston. And from time to time, they sent a fax, and they say, “Please take in the spare boards, number X, and put it in slot Z.” That’s all. BBN was able to remotely monitor the node and required local action when it has detected a fault in the memory card, in the processing card, or in the I/O card. And they were also controlling traffic and quality”.

Needless to say that I was already very impressed but it was just the beginning of the story.

When I came back home I had to make a decision for the research domain I wanted to tackle.

I had a live assignment to teach Systems Theory and Automatic Control. My three courses in this area were already available but I decided that I will not develop my research group in this area.
In 1972, I created a Research Unit in Networking (RUN). I focused my works on the protocol theory and on the network architecture. I engaged into cooperation with Louis Pouzin, Vint Cerf, Bob Metcalfe, and other researchers of ARPANET and Cyclades.

As I wanted also not to be confined to theoretical aspects, I look around for projects having research and development parts. I went to the biggest bank in Belgium. I finally convinced them that they cannot ignore what was coming, which will have an impact on their company. And I wanted to avoid for them to fall in a hole later on. The different phases of the project between 1974 and 1979 ended up in a network with 6 processing centers and 1200 branch processors deployed in 1982. Another project was with EDF-GDF between 1976 and 1978 for the specification and the validation of the transport protocol of RETINA. Another project with Bell Telephone (Alcatel Bell-Anvers) between 1979 and 1981 for the verification of internal protocols for the X.25 network developed by Bell Telephone for the Dutch network. During the three projects, I have developed models for the representation of the network protocols and have studied formal methods of specification and verification of network protocols. Of course the network architecture aspects were also an essential part of these projects.

I did also, in the seventies, one thing I am very proud of. During the seventies, everybody was organizing Computer Network Conferences. After Arpanet, you know, it was clear that the computer would have to work in networks. These conferences were of course interesting, but they were covering everything. They were covering the hardware, the software, the technologies and the

applications. So it was a kind of general conference with only half a day about the subject which I have interest for my research. In 1978, I organized, in Liège, the first world conference dedicated on "Computer Network Protocols" which was attended by 480 participants.

Since '72, I had been seduced by the protocol. Not by C++, neither FORTRAN, but by the concept of the protocol and by the way it was developed. It was really done without strict methods. If the research for the space program had been done with the method of the computer science, the Sea of Caraibes would be full of astronauts. Because it was a trial-and-error method. You try, it works. Okay. It doesn't work, it will work tomorrow, and so on. So with my background, I came to the idea that we must have formal language of programming in order to be able to prove properties of the program, prove that the program cannot stop in a place where there is a deadlock whatever happens in the system. And so we begin to work on formal matters, and because this has a mathematical inclination this gives me some satisfaction from an intellectual point of view.

Russell: More science than engineering.

Danthine: Yes. Or more precisely, I would say more science to apply to engineering. Of course, when you do this kind of modeling with a formal language, you do not always cover all the situations. But we were successful. During the 20 years, we used several techniques, and we developed – not only my group, but a large group of people – two languages: Estelle and LOTOS. These two languages had been standardized at the ISO. It was useful.

We made interesting things. We avoid problems for Alcatel when they were developing the X.25 network of the Dutch PTT in Holland. We model the protocol with our formal methods and proved that there was a deadlock. Alcatel told us "that if the deadlock had occurred in operation, they were wondering how long it would have taken for them to find out the origins of the fault." It was a very complex procedure and probably very unlikely to happen. But it was possible. Of course if we found the fault, we found the cure, and Alcatel were very happy to have funded this project because it produced a proof of a potential deadlock before the implementation of the system.

But it is fair to say that the larger the problem, the more difficult to model it and to apply the formal methods. If the problem is divided in smaller pieces the situation is better but it is necessary to proof that the sum of the pieces is equivalent to the global problem.

In the beginning of the eighties, the Commission of the European Community started to prepare a European Program of Research, a kind of European Science Foundation. Have you heard about it?

Russell: Only a little bit, can you tell me about it?

Danthine: It's kind of the equivalent of the National Science Foundation for the European countries, for the European community. Okay? So they launch the program "ESPRIT". I will pass the details of the genesis because it was a little hectic on the beginning. Eventually, in '83, they start the first call for project proposals. If I remember right, there was 200 submitted, 13 selected, and I had one of them.

Each project must have a consortium of countries (2 or more) and be a mix of industrial companies and academic institutions and research centers. You must have good contact in order to make good project, of course. My project (ESPRIT 73) was the only one that was driven by a university and not by an industry. This project aimed at the development for the interconnection of heterogeneous LANs on a broad site. The project concluded in 1989, with the installation on the Sart Tilman Campus of the University of Liège, of the BWN (Backbone Wideband Network) prototype [with] more than 18 km of optical fiber with a data rate of 140 Mbps. My group has been responsible for the architecture studies, the formal specifications of all protocols as well as the methods for the performance evaluation and their practical implementation. Alcatel Bell in Antwerp and Stollmann were responsible for the design and the realization of the gateways.

The BWN has been used to support the development of a new concept of a corporate message handling system and to demonstrate the multimedia capability of a connectionless network by successfully supporting video transmission at 2 Mbps through the BWN and the 2Mbps bearer service of the historical operator between Antwerp and Liège. Between 1986 and 1989, my group was a member of the consortium of PANGLOS, the ESPRIT project 890 for the design of a high performance gateway. Until 1997, my group has been always involved with often several projects in parallel in the European Research programs ESPRIT and RACE. During this period I tried to stay with a maximum number of 10 assistants and researchers with me.

Russell: In your group?

Danthine: Yes, because at a certain moment, if you go too far, you are not anymore able to follow them, and also, you are not anymore able to keep a personal research what I wanted to keep completely disjointed from the contracts. No problem. I was not going in biology.

1997 was the end of my University career. I am now Emeritus Professor. I was replaced by two colleagues, one for the automatic control part of my heritage and by Guy Leduc for the computer networking part and for RUN. From October 1997 and 2000, as the inactivity was not an option, I have presented many one-day tutorials on IP over ATM and on MPLS in many conferences in Milano, Cannes, Sydney, Madrid, Asuncion, Buenos-Aires, Split, Bangkok and Riverside. In 2000, I founded a company called NETiDA (NET for network, DA for Danthine André and between, "i" for the phonetic aspect of the name. We were at the end of the 90s. It was the end of the ATM saga and at that time I was already engaged in the research on MPLS, which started in '98. And I decided that all Telco companies, all the historical operators, would need an expert to tell them why and how they have to quit TDM and go to IP and Internet. All my presentations were now 2 or 3 days in order to be able to go in-depth of the subjects. There are presented on-site for a group of minimum 6 participants. And this is what I do for more than 10 years now.
Of course it was not easy because I created the company in 2000, and in 2002, there was the Internet bubble. So no more training money for the companies, even the big ones. After that, I restarted but in 2008 came the financial bubble but I have been able to survive.

Russell: And still find something to do as well.

Danthine: Yes, yes. Finally I concentrated on the three lower layers of the OSI model: IP plus MPLS, Carrier Internet, and IP optical. Of course, it's clear that for people like me who have not an enormous budget to spend on documentation and travel, we must be able to keep in touch with things when they happen. And the only place where you can that is IETF. Because in IETF, you will be able to follow the activities of the working group of interest for you. You will get all the drafts and of course all the RFCs. With a few friends working actively in the IETF meetings, it is possible to get documents distributed in the meetings and get some hint about the trends. In ISO, it's impossible because it's an organization of national countries. In ITU-T, it's impossible because it's only for the operators. And in IEEE, it's not easy because you cannot have the drafts, and if you want to have the standard, you have to pay for it during 18 months. After that, they become free. But 18 months after the standard, it's not at this moment that you teach the companies what the standard is doing. It is a pity that IEEE never found a way to provide free access for the drafts on standards under study for the academics interested in the subject.

So does this give you an idea?

Russell: Yes, your career trajectory and the scope of your research are much clearer to me now.

Danthine: Now if you look in the period of '72 to '97, it's clear that I am in Europe, and from '83, the program of research in the European Community was main source of support for my projects and for the projects where I was partner. So we were pushed by the European Community, sometimes in directions that we do not like. But it was necessary to be flexible in order to get inside the framework they had defined. And it's clear at certain moments we diverged completely from the US. Take X.25

and Frame Relay. Frame Relay had been much more successful in the US than X.25 had been in Europe. AT&T has more than 100,000 Frame Relay customers still now. And Frame Relay is, in the spirit, very close to X.25 but more clever. This is not the first quality of a Telco. It is organized. It does not like shortcuts. It has been able to make a connection from any telephone to any telephone in the world with a quality of service that was excellent because when you phone in Australia, it's like next-door quality. So okay. But it took more than 100 years to have a perfect world network.

Russell: It needs to be slow and orderly.

Danthine: And bigger and bigger and bigger. And coming back to our problem, we were more or less obliged to follow the OSI model. At some moment, we were able to push for a mix with IP over ATM. ATM has been a very interesting technology to study.
ATM has failed for several reasons, but first, because when you introduce competition between the Telcos, don't ask them to develop a world network by cooperation. In the past when the historical operators had a monopoly on territory, a country, a Telco had no problem to cooperate because it had no other choice. They were inclined to cooperate because they got the support for their neighbors and everybody was just increasing its activity. Their footprint was completely fixed. With the de-regulation of the monopoly of Telcos, they became competitors and interested to increase their footprint and at the same time fighting against newcomers on their historical territory,

Internet is the only case of what I call a *biological* network. It grows from itself without any central management system. Each AS in the Internet has to define its rules of cooperation and to implement

the BGP protocol to be part of the Internet. Internet is fully distributed system and behaves as a biological system.

Russell: I want to go back and ask for some details here and there. You said that you found out about the Arpanet node in Illinois from the press.

Danthine: From the press, yes. It was the announcement of the beginning of the ARPANET. As you know, in Arpanet, what you have is the universities of east coast and of the west coast and, in between, in the American desert, a few universities like Illinois and a lot of military bases.

Russell: So it was just in the technical press?

Danthine: Yes. I am a member of IEEE and ACM, from the very beginning of my career as engineer.

Russell: Who was the contact at Illinois, the guy who you said was on vacation and was in charge of it? Do you remember?

Danthine: My first contact in Illinois was my colleague involved in optimization theory. The people on vacation were from the computer center, responsible of the IMP. I do not remember his name.

Russell: Right, okay. You mentioned that the Dutch PTT commissioned you to work on an X.25 network, and you proved that it would deadlock. Do you remember what year that work was?

Danthine: Yes, it was between 1979 and 1981. During my career, I changed several times my personal computer. It has been difficult to save all the content of the old PCs. They make different types of archives which later on you are not anymore able to access. Of course, I made also paper copies but after more than 40 years, several closets are full and I always hesitate to begin a search. Why I switched to the RACE from ESPRIT? ESPRIT was computer science and RACE was communication oriented. It was the domain of the Telcos, and the other was the domain of the computer science companies. And I was interested in ATM and in the contacts with the telecommunications companies. In 2000 and 2001 I did many public in-depth tutorials, which were organized by companies which were specialized in this kind of job in Paris, in London, in Brussels. But 2002 was the year the Internet Bubble blew up.

Russell: The crash? The dot-com crash?

Danthine: Yes. A big slowdown in activities with training and budget reduced everywhere. After that, it was impossible to restart the public in-depth tutorials. And I jumped into the idea of doing on-site training for specific companies. And I did also some one-day tutorials at conferences because that was still possible in 2001.

Russell: You also mentioned that you developed networks for a bank in the 1970s. That must have been a challenging and fascinating project, given the scale of banks and some of their unusual and specific needs, such as reliability and security.

Danthine: The *Société Générale de Banque* was the biggest bank of Belgium with 1200 branches. At the end of the project each branch was equipped with materials from Digital, DEC. These equipments were manufactured in a special factory working 3 years to equip the 1200 branches. Each branch had a modified PDP computer from PDP 10, 11, …up to 45 depending of the size of the branches (1 up to 45 people for a branch). The price of this contract was 1.4 billion of Belgium francs (around $560 million). The PDP had no diskette reader. You are in a bank, you cannot introduce, and you cannot collect information from the system. You cannot print the name of the client. Everything was centered on the idea that each branch was online to transfer all the operations to a processing center. There were six in Belgium. During the night, a batch process was run to update all the accounts of the processing center.

At that time, there was some hole in the security because the accounts were not modified online but modified every day by the batch processing. If I had an account in this bank, and I was able to run the same day to many branches, I would have been able to collect several times the amount of the account. The bank knew that, but say, "Very unlikely." In fact, it was never a problem. The most difficult problem for the bank was the three years of negotiations with the union. Because the union wanted to be sure that nobody would be fired. The bank had to promise that they would not fire anybody. They will wait until people leave from natural solutions (pension, leaving).

During the negotiation of the project for the bank, I insisted to the need to follow the research and the development on the network based on packet switching. In 1974, I and the two researchers funded by the bank closely followed the activities of ARPANET and its International Packet Network Working Group (INWG), of Donald Davies in U.K. and of Louis Pouzin and the CYCLADES Group in Paris.

We prepared reports and each year, I made a presentation to the bank. During this period we got few questions from the bank except that they asked me to make a mission [to] a bank in the U.S. who claimed to have a completed installation. They sent me there with a staff of the bank to look at it, and we realized that they had it on paper. It was completely designed but nothing was implemented not even on a prototype. But the bank representative was already impressed by the paper design.

Sometime in 1977, I got a call. “We would like to see you in Brussels next week”. In this meeting, they told me that they wanted to start to cooperate actively with us to evaluate if it was possible to design a network. They built a taskforce in the bank in order to analyze every transaction possible in a branch. And for every transaction in a branch, the taskforce evaluated the procedure, the processing time and the impact on the communication between the branch and the corresponding processing center. They had at the beginning 96 different transactions per branch, but we ended up with only seven or nine transactions which were significant in terms of volume of processing and of volume of communication. And on that basis, we were able to finally have a base to design a network which was supposed to offer to each employee of a branch the same efficiency. Remember that we had a continuum of branches from 1 up to 40 employees, with traffic on the fly. In parallel with the evaluation of the loads, we prepared a configuration of the network. It was of course with X.25 with high security. We had two X.25 lines per branch as it was not possible for a branch to stay alone more than half an hour, without downloading the transactions. It took us two years and a half to make the design and make a simulation of the complete network. In parallel, the bank started to negotiate for a manufacturer and it was finally DEC who got the contract.

Notice: the Belgium historical operator was not in a position to provide an X.25 service and agreed to give 5 years to the bank to operate the X.25 network. After 5 years, the historical operator was providing an X.25 service but as the daily traffic of the bank was equivalent to the monthly traffic of the public service, they choose to extend the privilege. So for your question about EDF, it was ’76 to ’78. At that time, we were working on what will become TCP. It was not existing yet. Okay? We had already the idea clear about IP, but the integration of TCP and IP – or IP and TCP – was not yet done at that time. And it was in ’78 that I made a big conference that I mentioned earlier. And for the Bell Telephone, it was between ’79 and ’81. X.25 was used for many years in Europe. Many years. Now we begin to see that it’s replaced. Carrier Internet will completely replace it.

Russell: You have anticipated many of my questions, and answered them before I have been able to ask them. One of my questions was to ask you about the source of your inspiration for getting into networking. But you already described your first encounter with the Arpanet…

Danthine: I have been seduced by the idea of this network. In Arpanet, you have people like Vint Cerf, who was a visionary. Vint has been Assistant Professor in Stanford from 1972 to 1976. Rumor said that he did not get his tenure because he has not enough scientific work. From 1976 to 1982 he joined to work with Bob Kahn, who is really the man who made Arpanet because he had the money. I was also in contact with Bob Metcalfe. He was at MIT at the time I was there. I crossed him. I saw him a few times, but I didn’t know what he was doing at that time. And when he was engaged at Xerox PARC in 1973, I learned about it – I don’t remember where. But when I was in this area of San Francisco, I decided to try to join him and called immediately. He said, “Come down and take a lunch with me.” I visit him several times. In 1980, he give me the material to make my first Ethernet

network with the big yellow cable. It was not the PARC Ethernet at 2.94 Mbps (because they found a box of oscillators at this frequency…) It was a DIX Ethernet at 10 Mbps. I can show it. It's still here. It's still working. I had the first Ethernet in Belgium and maybe one of the first installed in Europe in – if I remember right – 1981.

Russell: And then what about other Europeans?

Danthine: Okay. We had very good contact with Louis Pouzin. He had a group which was developing Cyclades. We made the formal verification of the Cyclades protocol. Louis was very badly supported by the government in France. You know that because you just met him in Paris. But we had very good contact also with [NPL's] Donald Davies and its one node network. In the U.S., I knew several people in Bolt, Beranek and Newman, like Alex McQuillan. It was a very open community, always growing. John Day came later on with his very strong views. But most of the people which I worked with were people which were already involved in the beginning of the 80s Internet work.

Russell: International collaboration took place in the early 1970s, in the IFIP 6.1 or INWG group. How did you get involved with that?

Danthine: INWG, International Packet Network Working Group was created in 1972 to produce numbered notes as report on discussion or consensus at meeting or as contribution of a participant for the next meeting. The notes (on paper) were distributed by DARPA. Louis Pouzin, a member of this group from the beginning, was at the time chairman of the TC6 (Technical Committee 6 – Data

Transmission) of the IFIP (International Federation of Information Processing). He made INWG part of the 6.1 Working Group of the TC6 of IFIP. By so doing INWG was able to participate to the meetings of CCITT and ISO and to provide inputs on packet networking. I organize a meeting of INWG , under the chairmanship of Vint Cerf, after my conference on Computer Network Protocol in 1978. Louis Pouzin suggested to me in 1977 to participate [in] the TC6 as the Belgium representative. My designation was done the same year and I was elected TC6 Chairman in 1979. I served two terms until 1985. I followed the INWG activities since 1977.

Russell: Can you tell me a little bit more about the conference in 1978 that you organized here – the conference in networking?

Danthine: The conference in networking was focused on the concept of protocols. The conference presented various models for the representation of the network protocols. Some other papers presented formal methods for the specification and the verification of network protocols. Several protocols already implemented such as Cyclades were also discussed and last but not least, the newly standardized X.25 protocol was discussed. X.25 was standardized by the CCITT (now ITU-T). It is fair to say that France Telecom and Bell Canada pushed a lot for the standardization of X.25 because they wanted to start a data service called respectively Transpac and Datapac. It is over Transpac that the French Minitel was supported. It is in a conference in Toronto, in summer 1977, that newly standardized X.25 protocol was officially presented.

During this conference in Toronto, I presented a paper and I quit smoking the same day. A very important day for me. I was smoking 50 cigarettes a day. Not smoking completely because I was lighting a second cigarette when the first one was unfinished on the ashtray. It was a real addiction.

At the end of the academic year, I told my students that after the vacation, I will not smoke anymore. I told the same thing to my family, my friends and anybody I met during this period. I wanted to burn my vessel like *Christophe Colomb* when he arrived in America.

Russell: This was 1976?

Danthine: 1977. Because it was at the conference in Toronto. After the conference I put about five packets of cigarettes in the toilet, and flushed with a pleasure, a kind of physical pleasure – to destroy five packets of cigarettes, which was what I took in order to be shored off before my presentation because I did not want it to be in a hectic state. If you want to stop, you must never say, "I will try." You must say, "I will do it." I knew the mechanism which try to force you to smoke. When you go to the sea, after having a good swim, very few people try to jump on the cigarette immediately. There is no need for it. When they are in a meal, many people try to smoke during the meal. Why? Because the nicotine comes from the transpiration. And when you go out of the water after a shower or after the sea, you do not have any vapor of nicotine which comes in your olfactory system in order to say, "Smoke, smoke, smoke." So I took three showers a day – at morning, after dinner, and before going to bed. And it was easy. I have never had the impression that it was difficult to stop smoking. It became more difficult, three months after, during meetings with smoking people. Fortunately today the rule is "non smoking meeting".

Russell: Yes, others have remarked how classrooms and meeting spaces have changed over the years in that regard. Back to INWG – there was a bit of a split between the Arpanet people who wanted to develop TCP and had pressure from their military sponsors to implement TCP; and, on the other

hand, people such as Pouzin's Cyclades group who had some slightly different ideas about transport protocols and different pressures from their sponsors in the French government.

Danthine: First, ARPANET was different from Cyclades. Arpanet wanted to provide a message service and Cyclades wanted to provide a packet service. INWG was a very active group with two subgroups to address the "Communication System Requirements" and "the Host-to-Host Protocol Requirements." INWG produced a lot of documents with a few corner stones. Vint Cerf after the meeting in N.Y. in 1973 was the editor of INWG 28, a draft of an International Transmission Protocol (ITP). This document was prepared by a small team of engineers with implementation experience from ARPANET, Cyclades, MERIT (US), and NPL (UK). One month later, INWG 39 was distributed by Vint Cerf and Bob Kahn. In October 1973, Louis Pouzin distributed INWG 42, a tutorial on "Interconnection of Packet Switching Networks" introducing the term of "catanet" (for "concatenated networks"). In April 1974, Hubert Zimmermann and Michel Elie, from Cyclades, distributed INWG 61 "Standard Host-Host Protocol for Heterogeneous Networks". In May 1974, the paper by Cerf and Kahn, "A Protocol for Packet Network Interconnection" was published by IEEE; it was an updated version of INWG 39.

Because INWG needed to move forward with only one protocol, Pouzin and Cerf called for a mail vote to an End-to-End protocol, INWG 96, before forwarding it to standards bodies. All members of INWG announced they will switch to the new proposal except DARPA. They stayed with INWG 39 because they were too close to completing implementation of INWG 39 and would not switch to another design. This was a surprising statement as ARPA had a bigger research budget than any of

the other research organizations. It was a pity that a joint position of U.S and Europe has been missed.

But what many people ignore is that the cooperation of Europe and the U.S. was tremendous about Ethernet. In 1980, IEEE decided to get involved in the standardization of Ethernet. The standardization of Ethernet was also prepared by Xerox and by Bob Metcalfe. The group called DIX (Digital, Intel, Xerox) published, in September 1980, a blue book. This DIX standard was needed to support the activities of 3Com founded in 1979 by Bob Metcalfe. In the IEEE standardization group on Ethernet, there was a fight about the length of the address. A lot of people wanted 16 bits instead of 48 bits of DIX. And during months and years, it was impossible for IEEE to get an approved proposal. In the meantime, a lot of material were produced at 3Com following the DIX standard. 3Com got a very good help from a company in their neighborhood who had been able to make a board for PC with the DIX. And it was the very beginning of a success because it was probably the most successful interface that was ever built in the world.
At IEEE they stay face-to-face without accepting to integrate Ethernet DIX in the standard with also the position of the group requesting an 16 bit address.

The European Computer Manufacturing Association (ECMA) played an important role. The members are the European manufacturers such as Alcatel and Siemens but also American manufacturers having production plants in Europe like IBM and Xerox. ECMA decided to present to ISO a proposal for the standardization of Ethernet based on the blue book. All the other European manufacturers were absolutely delighted to go into a proposal which would make them very famous. It was of course a panic in IEEE because they realized that they will lose the leadership on Ethernet.

So finally they were able to find a compromise to reach the quota for having the standard. This standard of IEEE is based on a 48 bits address with an option for 16 bits. Behind this option, were people who wanted to use Ethernet for the process control in factories where they have small footprint and a 16 bit address was enough. The IEEE protocol for Ethernet has been revised after 20 years. They decided to suppress the option of 16 bits address that has NEVER been used.

Russell: You said you were Chairman of IFIP TC6'79 to '85. Can you tell me a little bit about what was going on in TC6 and what your duties were as Chair?

Danthine: X.400. Of course all the work on the protocol itself – because the work on 6.1 still existed – was a formal matter. It was there that we worked on Estelle and LOTOS and everything. But during this period, a very important work has been done in messaging systems. And of course of that finally the only thing that survived is X.400 because finally the mail is still the Internet mail, right? Simple. Dirty, but simple. Not very elaborate a system. Of course what we did in TC6 was a proposal which was presented at ISO, supported by ISO, but never developed as a product.

Russell: Who were some of the most active people when you were in TC6?

Danthine: Ron Uhlich. He was really the person behind that. He was from Canada. He was Chairman of Working Group 6.6 actually. But I cannot put my hand in the fire for the number of working group which was taking care of the messaging system.

Russell: Okay. Did you have conferences regularly?

Danthine: No, we did not. The way we work is the following. In TC6, from the very beginning, every working group has to define its aim and scope. It's published. And it has to be based on a group of people who present to the total TC6 group: the idea which they have or they want to do, and what they intend to do for meetings, what kind of meetings, periodicity, what kind of public activities they want to make, conferences, work with different types of events, workshops, or invitations, you know? Normally it's because they do not want to publicize widely, and it's 20 to 50 people. Small conferences – less than 100 people. And then there is the big conference, which can go any place from several hundred to, you know... we call a flagship, okay? Which is *the* annual big conference which turns around the world, never at the same place. Every big country can apply to organize it at the TC6 meeting where we make the decision. Okay? Of course we have manufacturers who come to organize it because we are all without, because nobody's paid at TC6. Nobody is supported. All your support has come from a program of research. We have only money to support attendees from developing countries, college students, things like that. But all the people in the community, the travel expenses are on your own. Even for the TC Chairman. And there is a lot of difference. For instance, there was at the high-speed network, which became the big conference flagship, which is networking conference, is always 200 to 500 people. And it's big even. The last one I have been involved in with some research from here was in Paris. And I got as a keynote speaker Bob Kahn.

Russell: You earned some international recognition in the 1980s: Governor of ICCC and then the Bell Telephone 100th Anniversary Prize. I wonder if you could tell me about those.

Danthine: ICCC is an organization which was very successful in the beginning of the 70s. It was controlled more or less by the Telco. Lots of people will come from that group. I had been nominated because I was not from the top. And they wanted to include the development of what would become Internet and so on. But they have a policy which is a very big career; they have all these companies which are very well represented in this group of ICCC honors. All of them have international visibility. And what they tried to find is country who want to make visibility for the country. What they do, for instance, with India, we paid a very big conference in India. They wanted to have the conference at any cost. And what ICCC said is sell the name of the conference for a certain amount of money, which enabled to have support for the administration of the ICCC and the permanent staff, which is at Washington of course. Okay? And but they're responsible. And ICCC brings what? They bring the people that sell, which may collaborate for making proposals for subjects, for papers, and things like that. And organized the control of quality.

Russell: And the Bell Telephone Prize?

Danthine: That is a completely different story because Bell – Alcatel Bell in Belgium – is dependent at an early time on Bell Telephone U.S. After that there was change. And finally today it's built entirely from Alcatel France. But the 100th anniversary of Bell Telephone in Antwerp, they wanted to mark the event. Okay? And so they decided the best way is to make a prize, you know, interesting. A good prize. Ah, yes, at that time, it was 2,500 Euros, which is a sizeable amount, out of tax because they use the Belgian National Science Foundation, which is a completely research institute, which distributes grants for researchers. And this National Science Foundation in Belgium is financed by a percentage of the support of the university. The state pays for the universities in Belgium. You know

that we are a socialist state, of course, as most of European countries. Okay? We are not a capitalist state like many places in your country. Okay? And therefore, the budget of the university is decided by the government. And when they fix it, immediately we take a percentage, and the National Science Foundation in Belgium knows what is its budget and gives grants for researchers, qualifying researchers, Masters of research, which are a career which is almost parallel to the career of the professor at the university, but only for the research. They are allowed to give two lectures a year, two lectures of 30 hours. No more. They must do research. It's a real parallel organization. And they do not cover the complete spectrum. They try to stay in a spectrum which has some momentum, you know, also to support big equipment which have to be bought by the researcher and some place. And so the Bell Telephone asked the *Front national* to organize this competition for this prize. And of course it was defined as would be in the area of computer network, etc., and so forth. So I applied, and I got it. I think we were three people at the same, in Belgium, okay?

Russell: One thing that stands out from your publications in the 1980s is an increasing interest in LANs. You've already spoken about Ethernet a bit; can you say more about the broader context of LANs? You were publishing and working both with OSI and the Internet communities.

Danthine: I did some things with OSI, especially in ISO. But my main contact was Internet. And I would like maybe to stress one of the research projects of the Commission. The first one I got was in fact in '83. My idea was the following. It was the beginning of the interest of looking at the problem of carrying on Internet video and traffic like voice, which is characterized by connection orientation and timing. And it was a time also where the people which were on the side also of Telco were discussing ATM because ATM is asynchronous. A lot of people do not recall that A is asynchronous.

And this asynchronous is there to transport connection traffic because the first application of ATM was formed. And therefore, there was a kind of mix of ideas – the ATM idea by the asynchronous aspect, making flexibility in the switch – and at the same time, it seems to offer the same service that a few connection-oriented environment. And so the goal I tried to pursue in this project of the European Community was to build and take a campus, which was a big LAN. Okay? In fact, it's a multi-LAN environment because we have a LAN a building, if not more. And all this from without leaving out of the environment of the campus is one big LAN. Okay? So my idea was to first explore the high-speed because I wanted to have a high-speed network. And in '83, my proposal was to have a ring of 140 megabytes per second. And we did it. We did it with Alcatel, with ACEC and with Stollman in Germany, and so on. It was a big project. There were 12 nodes on this campus. And what we wanted to see was the following. Alcatel is located in Antwerp. They will use a leased line to bring us a video through a codec, which was synchronous. This traffic will arrive at one of our access points here in my lab. In this lab, we will packetize the video because the network is a packet network. Pure Internet. And we sent this packet through the network. And I have a second node in my lab where I receive the packet, which returned, which have done the complete tour. In every station, in the first station, I have the possibility to have background traffic, Internet traffic, just to load the network. And we had designed the technique which is now very common, which was done in cooperation with Bell, of solving the resynchronization by just buffering and having a buffer which is bigger than the jitter. No way. Things which are simple are the best. Okay? So what you have, you have your packet which starts synchronized, which lose synchronization because they have to compete in every switch. They come back with a small jitter. But in order to give the good behavior, you have to restore the synchronization. So what you do is make a buffer and organize, maintain the order and resynchronize it at the hop. And in order to be sure this signal was

synchronized was sent back to Antwerp and put on another screen, another TV, in order to see how the signal was after making this roundtrip. And what was really surprising for us because we were not expecting such a result, it [began] to de-synchronize when the background traffic on the 140 megabyte was about 100,000 megabytes. So we were at 70% of the load, and it remained synchronized. And this was important for one thing: because it convinced even Alcatel Bell that ATM was feasible. And it was at that time that they made the vote for ATM at the ITU-T. Not for me… but Alcatel was convinced. You know?

Russell: Were you also convinced?

Danthine: I was convinced, but I was hopeful from the very beginning. But I had no… As soon as it works, it's clear that the activity for ATM was in the hands of the people from Alcatel because they are members of ITU-T, and I had never attended a meeting of ITU-T in my life. I attended ISO meetings in Korea and different places. We also work on the idea that it would be interesting to have a change of the transport protocol for having new service in connection with the type of traffic, like videos and things like that. Okay, it was an exploration of what is the QoS [Quality of Service]. You know very well the network. May I ask you a question?

Russell: Of course.

Danthine: With classical Internet – so without any tricks in the switch – it's the best effort. It's called the best effort. Do you believe that this behavior has a quality of service?

Russell: There is *some* quality. It depends, I think. Not a consistent quality, no.

Danthine: No. Are you sure? You will have problem at my exam. <laughter>

Russell: There are so many things in the middle, right? Sometimes I request a video stream over the Internet, to watch soccer from Europe. And the video…

Danthine: I don't speak about video. I speak about best effort in packets. Could you name the quality of service of the packet transport of an FTP packet?

Russell: No.

Danthine: I can. That's the reason why I am the professor. <laughter> I guarantee the content. Any FTP which is sent on an Internet in best effort achieves a transfer of the content. Otherwise, the FTP fails. So when the service is given, it has a quality of service of content preservation. Surprisingly, nobody mentions that very often. We speak always of delay, of timing, of bandwidths. But in fact, it's believable because it was at the origin of the TCP/IP. It was that that we were discussing in INWG. It was to preserve the content. When you finish your FTP, you have it, or you have nothing! So if you are unable to provide the service for any reason. Lack of bandwidth, for instance, or time outs, which become unbelievably impossible to handle. But when it works, it works perfectly. So you have a quality of service.

Russell: You're right, it's not usually discussed that way. But now that you mention it, it makes sense to me.

Danthine: I think it's important because, you know, I came to this argument because I was upset when I was around people from the Telco they were always telling me that there was no quality of service. And finally I had to find an argument. And finally I found it. And at every conference, I take my hammer, and I hammer on the nail.

Russell: It's a different concept of quality than on a telephone circuit, where you can have interference or distortion in a telephone call.

Danthine: Yes, what you have in a POTS is a connection, a very well established connection, but here the quality of service depends upon the quality of the signal transmission. You may have a connection but be unable to get the message.

Russell: Good. Okay, let's see. To return to your career in a chronological sense, we were discussing the late 80s, early 1990s, and there are two things I wanted to ask you about there. One was an article you wrote in 1990, "Ten Years with OSI," from an IFIP TC6 meeting. And the other is the creation of OSI '95.

Danthine: OSI '95 was a research project where we wanted to investigate the concept of the QoS. It was a book, finally. It was a book, a set of documents. I must say we tried to push this through the ISO, without success. Of course it was impossible to push it at the IETF.

At the time of OSI95, I realized how far were the Telco people from the concept of the packet communications. <in a whisper> They do not understand. You know? I go to people that are offering Internet connection with DSL and so on, but they do not have a clear idea how Internet was working. Most of them never heard about BGP. Believe it! They do not even understand the principles of the routing in IP. They are convinced that, in IP, it's impossible for the people who work in '78 to design a system without the establishment of a connection before sending the packets. They did not realize that, with the routing protocols that we have, we have the complete knowledge of the topology! And we would have been able to set the connection from this information like in the telephone systems. And the reason why packet people did not do it is simple. It's because the number of incidents at the beginning of the Arpanet and of the Internet was extremely high on a modem-based connection. The loss of the physical connections was very common and restoration not very fast. They take another way based on the routing protocol able to reconfigure the topology of the network. We know it worked. And at the end, now we do not have anymore of this problem because when you have an Internet link that is not anymore collision-based and is of good quality. We use fiber. At the end of the nineties, with the need to support not only data traffic but voice and video, the flexibility of TCP/IP to protect the content was not anymore acceptable and the idea of a virtual connection was one of the reason to introduce MPLS, able of fast recovery from trouble in the topology.

Russell: You said that it was impossible in IETF, so you had to go to ISO?

Danthine: Yes, to ISO. And ISO was too slow, too… We had a members' meeting in London where the Japanese were unable to understand exactly the concept of the QoS. It was cultural.

Russell: Why was it impossible in IETF?

Danthine: Because IETF will never change TCP/IP as the backward compatibility is a religion. For real-time transport, IETF introduced, side by side with TCP/IP, a real time protocol, RTP. But this is a second protocol, it's for the people who need it. It's another service. It's not anymore the transport, as we understand it, in packets. What IETF finally did is to introduce MPLS, which is the lowest slight part of layer 3. TCP is untouched. IP is untouched. And what MPLS did is two things. For a lot of applications, a connection is an asset. Such a connection must be established before sending the traffic. And if a connection is an asset, we must also take into account that the bandwidth is increasing, so it will be good to do what ATM is doing. Switching instead of forwarding by looking into the header at every hop. Instead of having a unique destination address, which has to be looked up at every hop, MPLS build a sequence of labels, which will be the key to make the switching on the fly Switch and swap, switch and swap, switch and swap. In the swap, the label of the incoming frame is replaced in the outgoing frame, by the next label of the sequence defining the connection.

At the end of the nineties, the MPLS idea has been very badly received by IETF. The MPLS working group has been attached to various sub-area to finally end up in the routing area.
When I got my ACM nomination award in 2001, I presented MPLS. It was an icy reception. I did a maximum to avoid to attack, but I reminded everybody that in every network in the world, between a router and another router, there is a connection. Sometimes it's a radio connection but there is a connection. And MPLS is just setting a virtual connection below IP. IP and MPLS are in the layer 3. It's not a layer 2. It's not a data link. And it is not an undefined layer 2.5! One of the assets of MPLS

is its aggregation capability. It is possible to aggregate thousands of "pseudo-wire" on a single MPLS connection. In the beginning of the nineties, many operators in US and Europe had ATM in the core of their backbones. But in '96, ATM equipments where still limited at 625 Mbps. Even if it was theoretically possible to go higher, no manufacturer was able to reconstruct an AAL 5 packet above that speed. It was a hardware problem, a technology limitation. During four years, all operators that I met in U.S. between '92 and '96, were desperate about ATM. And they began to switch back to Sonet and SDH and in '99, to MPLS. In 2006, 95% of the operators in U.S. and in Europe were MPLS based.

Russell: How does IP version 6 fit into these developments?

Danthine: IP version 6 is another story. Until now I was not interested to get involved because I will never, with my age, be able to make presentations of IP 6 useful for the operators I am working for. Carrier Ethernet and Cloud Computing were more popular subjects to tackle. Coming back to OSI '95, it was an experience of research, which helped us to understand things, but did not achieve tremendous results. But it clarified a lot of things. If you look at all the papers inside the OSI 95 book, you will not waste your time.

Russell: Okay. Thank you. I have only a few questions left. In 1992, you were named Chairman of the COST 237 Action on Multimedia Telecommunications Services. Can you explain what that was?

Danthine: All COST actions are supported by the EC (European Commission). All COST actions have the same background and the same structure. They covered travel expenses for meetings on a

subject which has been defined and for which interested people have introduced a type of aims and scope for providing discussion in meetings and trying to organize workshops and conferences. The COST delegates were nominated by the countries. There was an authority in every European country, which had received the role of nominating one responsible person for each COST action. Of course the national delegate must be involved in the subject of the COST action. At the beginning, a few people of different countries are drafting a proposal for an action and submit it to COST Central Office in Brussels. After discussions a final proposal is ratified and a COST action is created. This new COST action is announced to all European countries that are invited to designate a national representative. The national delegates have to select a chairperson to start the activities of the group to organize the official meetings of the action and to report to COST CO. The workshops and conferences organized by an action is open to any interested participant. Some of the national delegates are designated during the live of an action. Ghost national delegates are replaced as the travel expenses of delegates to attend meetings are supported by the COST CO. Most of these COST actions produced books, workshops, and in some cases, organized big conferences. Very often they pave the way for the constitution of consortia to make proposals for the big European programs such as ESPRIT and RACE.

During a professional life when you are in an area, you must be in everything which takes care of that area in order to remain visible. My group was dealing with the communications of video in OSI 95. When I launched COST 237 in Multimedia Telecommunications Services I wanted to extend the group of contacts and it was very successful.

Russell: This must take a tremendous amount of energy.

Danthine: Yes, but that I have.

Russell: I can see that! The specific questions that came out of OSI 95 were, as we discussed earlier, questions related to quality of service?

Danthine: It was much more wider at the COST 11 group because it was the global problem. There was all the types of video, which were addressed, conference meetings, streaming videos, video-on-demand, etc…. All of things were studied there, a protocol like DAVIC for instance, was managed there. It was very wide. Anything which can go under the umbrella is open.

Russell: The key is to create an institutional basis for collaboration.

Danthine: Yes, and exchanging ideas and see who is interested to work in this subject. And after that, you create more groups inside COST 237, and they may activate any kind of procedure.

Russell: Americans traditionally interpret this sort of thing as overly bureaucratic. But from what I understand, this sounds like it is the only way to make it happen.

Danthine: Yes, it's a way to get the possibility to meet without relying on non-existing budgets. These travel and accommodation budgets were very small but extremely useful. Furthermore, each COST action had a company taking care of the administrative aspects – invitations and things like that. We do not have to worry about that. It's done and paid by the Commission.

Russell: This leads nicely into my next question. Can we step back and talk about the broader political and economic contexts in which you worked? It's very clear that the European, transnational context has made all the difference in the growing European Community. I wonder if you could say some general things about that, as well as the specific dynamics of deregulation or liberalization in Belgium, to the extent that that's made a difference. I know in America there's one story. In France there's a different story. I don't know the Belgian story well.

Danthine: France Telecom was very, very slow to apply the rules of deregulation, which were dictated by **a government agency.** FT deregulated at the level of the DSLAM [Digital Subscription Line Access Multiplexer]. But they asked a price that was too high for the competitors. It was difficult to put pressure on FT. The government agency was unable to get from FT an answer to the question "How many people will be able to get an Internet connection?" FT was not very interested to deploy a lot of DSLAMs to offer Internet Connection to residential users and so doing being obliged to give access to the DSLAMs for the competitors. But at a certain time France Telecom fell into the hole, because they demonstrated that they were not able to manage the numbers. So at this moment the pressure was immediate from the government to deliver a connection to the competitors because FT claimed not to be interested by these accesses but prevented the others to use it without any concurrence effect to them. And so they were trapped into a corner. It has been settled down slowly. Now there is fiber, which is coming from everywhere.

In Belgium, we have Belgacom, a private company owned by the State, which follows more or less the Regulator. But I would say that, in Belgium, with the density of population and the importance of

the cable companies, with Telenet and VOO, it will be impossible for Belgacom to ignore this competition. So I would say that here we do not have too much problem to get the connection.

Russell: Did these sorts of regulatory considerations ever intrude upon your research or your research agenda? Did you have problems or pressure from the Belgian government? Did Belgacom take an interest in your work?

Danthine: No. You have to see that there are two actors on the scene – the provider and the customer. And the most important customer is the corporations. The individual user will not ask for any research. The only group which was ready to be involved in the infrastructure, which is the domain where I am, is the people which have big installations with more than 3,000 people, have multi-sites and specific problems and requirements. On the side of the providers, I think that what they do for the moment is trying to follow Belgacom, which clearly is the most advanced from a point of view of knowledge and infrastructure. My group has very easy contacts with many competitors of Belgacom, some of them being interested to know more about the environment in which they are going to put their feet – soon or later. Our contacts are also easy with manufacturers and last but not least to what is called the "big accounts." Alcatel, Adva, and others manufacturers of equipments are doing a very good job. Alcatel has had a very difficult time with merging with Lucent. But now they begin to earn some money after losing tons!

Russell: It makes things better.

Danthine: Yes. As soon as it changed color from red to green, "Oooo!"

Russell: Much better!

Danthine: For instance, today the subject which will be probably the most interesting to study, if I was still in the research activity, is the global convergence not only between data, voice and video but also between wire and wireless communication, between small and big equipment. Behind the corner we will have to integrate in the converged world, M2M, machine to machine applications and the "Internet of Things". By the way, what is your view about the Cloud ?

Russell: I'm still not sure what it is, beyond a marketing term.

Danthine: Today most of the discussions are centered to the three types of clouds an enterprise may adopt: private cloud, public cloud or hybrid cloud. I am not sure that a public cloud offers today a secure, resilient and cost effective solution for an international enterprise. The list of pro and con for each category of cloud are too long. We will need a few years to see a clear trend for a large deployment. The first step of the evolution is likely to be the new generation of data centers as a first step for a private cloud.

Russell: I have two final questions. One we've touched on already concerns the booming Internet market in the last 10 years, waxing and waning at various points. There's a distinction to be made: in your early career, you did research on protocols – modeling, trying to do more theoretical work and contrasting the theory with practice. There is a separate domain as well – the problems of deployment and scaling up networks, making them faster, building and selling products, and so on. I wonder if

you could comment on the Internet as it's grown in the last 10 years and your view of how research activities have informed the design and deployment of Internet protocol 4 and Internet protocol 6.

Danthine: IPv6 is already available for those who need it. Three or four years ago, China asked IANA for 40 millions of IPv4 addresses but IANA was unable to provide. China was obliged to deploy IPv6. However the world migration will be slow. Today the Internet traffic on IPv6 is a fraction of 1% of the Internet traffic on IPv4. Now except for this case, which may come also in the picture in Japan, due to the "Internet of things" which is the multiplication of addresses, I think that besides that we can still live a lot without having a generalization of IPv6. The biggest providers of services have a world footprint, like the French company, which is the subsidiary of France Telecom for the international markets. They migrate first to offer MPLS everywhere. Now they will begin to migrate to offer IPv6 everywhere, but they will keep offering IPv4 also. The bandwidth is another problem. There is a classical figure involving the bandwidth capacity needed, the cost to offer this capacity, and the revenue for the provider. As long as the revenues are above the cost, it is fine but the problem is behind the crossing point. This chart is changing every year. And it's clear that the policy of bandwidth without limit will stop, sooner or later, even if today the photonic switching at optical level is ready to offer more capacity than the 400 Gbps Ethernet. Infinera has already made, in California, a long distance transfer above 1 TERAbps and they claim they intend to go to 10 Tbps. Of course we are here in a point-to-point transmission. To distribute access points along such link you need nodes. You need multiplexers and, if possible, flexible ones.

Russell: These are technical problems as much as they are economic problems.

Danthine: The technologies try to solve this problem, try to get a price per bit that decreases. And some operators try to attach this problem by refraining the traffic. This is a short term solution. There are years that people told me that we go into the wall, but fortunately, the wall is moving. What do you think about the importance of the cable network companies in the U.S.?

Russell: Increasingly there is no difference between what cable companies do and what telephone companies do. There are historical differences between Verizon, which is a telephone company, and Cable Vision, which is the cable company. But today I get TV from the phone company, but I know people who get telephone service from the cable company. The set top boxes for television, I think, are more or less the same. The speed of Internet service is as much as my computer – particularly my browser – can handle. The price is about the same. But one is regulated very differently than the other, and so that's the fight. Consumers in densely populated places have choices. In places that aren't densely populated, there's one provider or sometimes no providers of high speed Internet.

Danthine: And what about FTTH?

Russell: Yes, that's what I have. Fiber to the home, yes. But of course the fiber runs into the legacy coax cable that's inside the home, so I'm not taking advantage of it.

Danthine: You know, in my country, there is a completely unfair situation between cable companies and telephone companies. The cable companies started from television distribution, and they got the privilege to be allowed to put the cable on the buildings without asking the landlords except when the

building was classified for historical reasons. But now that they have this advantage, they keep it for other activities for which the others are not allowed to operate the same way.

Russell: Is there any prospect of changing that?

Danthine: No. It seems that nobody wants to engage this kind of battle.

Russell: It's a political question.

Danthine: Difficult to say.

Russell: Yes. Okay, my last question is about other degrees and awards you won, especially one in 2000, the ACM SIGCOMM Award for "basic contributions to protocol design and modeling and for leadership in the development of computer networking in Europe." Can you reflect on this occasion of winning the award and its meaning to you?

Danthine: Mentioning protocol work is very clear because I did a lot of things in this area with basic papers, with formal languages and with modeling able to prove protocol properties.
This was the scientific part of my contribution. And for the second point is because I have always been in all the groups which have advocated research networks in Europe, development of cooperation between countries, and also pushing the companies like the bank to invest in a big network. And I worked also for the European Commission in Luxembourg and in Brussels about their infrastructure to give access to all the countries members of the European Union.

For Peter Kirstein, the development of the computer networking was his main activity. He was *the* Mister Network Europe. He has been involved with the US from the very beginning of Arpanet. His first goal was to provide to UK the facilities available in the US universities. He was the evangelist of the integration of European countries into the Internet. Every time he had the occasion to speak, to move, to push, to write a paper claiming that it's not good. "Americans do that. Europe do not do it at all or do not do it at the same level." I was relaying his efforts in the continental Europe. You also want to know why I got two Doctor Honoris Causa degrees. At the University of Kent in Canterbury (1991), it was for my work with the TC6 on Messaging Systems. At the University of Toulouse (1996), it was for my works on protocol theory, in particular on Petri-Net and Estelle. I was working in close cooperation with the group of the LAAS-CNRS de Toulouse headed by Michel Diaz.

Russell: Do you have any final thoughts? Is there anything you thought I might ask, but I didn't?

Danthine: No, I don't think so. You have covered a lot of subjects. If you have a few minutes, just look through this material because you will have more details, and one question may arise just by looking. As you will keep this material with you, you will have time to look at it, but it's more easy to answer questions now.

Russell: Good. This makes me think of something else – your collaborators. You've published dozens of papers, and some names appear as co-authors more regularly than others. Are these students or fellow faculty here?

Danthine: They were researchers and assistants in my group.

Russell: You already described the various activities involved with the ESPRIT program, but I don't know if you described in general what that program was or what the acronym stood for.

Danthine: ESPRIT is the acronym for "European Strategic Program on Research in Information Technology." It began in 1983 with a goal to develop a program of research for Europe. Each country of the European Union had its program of research and the idea of the [Viscount Etienne] Davignon was to create a program of research involving several countries in order to avoid duplication and to accelerate results. Information Technology was an excellent framework for such program.
The Pilot phase of ESPRIT in 1983 attracted 200 proposals but only 38 were founded. ESPRIT 73 – Broadband Wideband Network – we already discussed, was one of them. The pilot phase was followed in 1984 by ESPRIT phase 1 on a four-year period and the successive phases of the program ran until 1998. RACE, Research and Development in Advanced Communication Technologies had two phases RACE 1 (between 1988 and 1992) and RACE II (between 1991 and 1994). This program was created for the benefits of the state-owned telecom companies while ESPRIT was more focused to the privately owned IT enterprises. RACE did the pioneering work in broadband and mobile telecommunications and in digital television. RACE program produced the ATM (Asynchronous Transfer Mode). ACTS, Advanced Communications Technologies and Services is the successor of RACE and ran from 1994 to 1998. Since 1998, the funding of the ICT (Information and Communication Technologies) is provided by the IST (Information Society Technologies). Today, the EC funding for the ICT is more than 1 Billion € per year.

Russell: Do you know, or can you comment on, GSM? It is often seen as a symbol of European technological integration. Were many lessons learned from GSM? Or did people or institutions carry over from that development into computer networking?

Danthine: It is in the ACTS program that mobile research, development and standardization activities related to the GSM have been developed. Transition to the 3G Mobile technology, development of new world video coding standards as MPEG 2 and 4, and of digital television standard DVB took place also through the ACTS. I was not involved in the mobile research part of the program but MPEG and digital video was part of the COST action I mentioned earlier. On the industrial side, GSM in Europe was for many years Nokia. It was really the booster. But as usual if you are the booster you have to stay at the head of the line. And now Nokia is in trouble, in big trouble. I have no comment on that. Management error is not my business.

Russell: We didn't discuss another project I see on your resume, the Pangloss project, which in 1986 began a parallel architecture for networking gateways linking OSI systems.

Danthine: We were involved as a very small partner in this program. I affected only one researcher on it. You must know what's going on. And as long as you have a small budget, you can keep an eye on it. Sometimes the participant was searching a subject of thesis. It may come from such a program. We have had examples.

Russell: Can you say a little bit about the professional societies – ACM, IEEE – and what role they've had in your career? You mentioned that you became aware of Arpanet because of the professional literature…

Danthine: This is completely different area. I am in the scientific societies because I need to have the maximum information about what happens which may have an interference with what I do. The publications of IEEE and ACM are the best sources of scientific information. When you work on a subject you cannot limit yourself to the publications which are just on the same subject than you. I want to look around by browsing through the publications of these societies. You must also be involved in the standardization groups. For me, the main development in standards was in IETF and, at a certain moment, in ISO. If I am dealing with a subject like MPLS, I must follow everything that IETF is doing in MPLS. For the moment, it's not mentioned there because it came after the 97, but I had also to follow the activities of the MEF. The Metro Ethernet Forum had a very important activity, handling the problem of the Carrier Ethernet. But this is an area where I did follow the activities of the MEF in order to be able to build my lectures for the people who need it and not to develop personal research because I had no more group since my retirement from the University.

Russell: What about the IETF? Unlike the ACM or IEEE, one doesn't become a member of the IETF, necessarily; one simply subscribes to mailing lists and goes to the meetings. Do you go to IETF meetings?

Danthine: I went once. But, you know, if you are directly involved in the ongoing standard you go to the meeting to contribute or you go to the meeting to follow the discussion to understand what the

active people are trying to do. They do not always tell you what is the goal. You have to find it. If you do not have the budget to cover the travel and the accommodation for attending the three IETF meetings each year, it is possible to study the various drafts and RFCs of interest to you. IETF has a very dynamic life. IETF is organized in several Areas and any working group must belong to one of the area. A WG may migrate from one area to another one. The WG on MPLS has been, at a certain moment, in the layer 2, later on in the layer 5 and finally in the layer 3 (Routing Area). IETF is a dynamic environment. But it's more flexible by being buoyant. In IEEE and especially in ITU-T, it's more rigid, it's more coherent, but it goes slowly and sometimes nowhere.

Russell: Do you see the future of protocols in an IETF type of organization?

Danthine: Of course, IETF is the place were the future of many protocols will be studied and standardized. But new organizations may appear. In 2001,a group of people realized that with Ethernet it was possible to go 10 gigabits and more. They created the MEF (Metro Ethernet Forum). The story of MEF is interesting. At the beginning of this century, the potential of increasing bandwidth was higher with Ethernet than with the classical technologies like ATM and SONET-SDH. Of course with DWDM more potential of bandwidth was available
People realized also that MPLS is well entrenched in a providers' network between the edge to edge. And what happens before the edges? It happens that we have access networks and aggregation of traffic. With DSLAM you go to an aggregation and after that you go to the edge of the provider. And there was the question to push or not MPLS closer to the user. Because of the goal of the service today for the user is end to end. Why? Because if you want to deliver a video, it's not the loss bit rate

that matters. It's the image that the client see. Is it satisfactory or is it completely messy? End-to-End is the new logo for the new generation, the new century, I would say.

We have already a solution well entrenched from edge to edge in the backbone, MPLS. Extend this solution end-to-end is possible but heavy. The environment of the backbone is a mesh network. The environment of the aggregation is often a tree network. And the environment of the access network is also a tree network. A Metro is very often an aggregation network. The MEF, at the beginning, was interested by a Metro based on Ethernet with the view that the Metro was the best place to deploy the high bandwidth offered by Ethernet. Not only the aggregation will be based on Ethernet but also the access will adopt it. After the DSLAM, ATM will also be replaced by Ethernet. There was clearly an interest to explore the ultimate capability of Ethernet. The MEF started its program by defining several Ethernet Services. By the way, IP service has no official definition of service. Some IP guru said, "The service is what the protocol does." The MEF wanted to build a MEN, Metropolitan Ethernet Network, where the end to end of the Metro would be a connection. Several connection types were defined. The MEF is not a standardization body. It is an association of manufacturers, of providers of service and of users that are interested in the development of the Information and Communication Technologies. It produces Technical Specifications resulting from the activities of working groups. The Ethernet Service Definitions are presented in several technical specifications. Besides requirements and definitions, Technical Specifications are produced for Implementation Agreements – these are very important for interoperability.

After three or four years of MEF activities, a lot of companies jumped into the definitions of the MEF and announced the service Ethernet. But no one service was equal to the service offered by a

neighbor company, and it was a complete mess. For the MEF, it was impossible to continue like that and they introduced the concept of a carrier-class Ethernet service. In a metropolitan network, a carrier class Ethernet service was associated with an SLA (Service Level Agreement) from edge to edge (from the ingress point in the metro to the egress point of the metro). This SLA was the specific value representing the Ethernet service. This SLA was the value guaranteed by the service provider and the customer must be able to control it. This SLA allows to introduce a value for the bandwidth and for quality of service. To achieve it, the MEF introduced, on each Ethernet connection, edge network devices, to support the OAM. Carrier-based Ethernet service was being very successful in the metro and the MEF realized that with a technology like Ethernet, there was no reason to stay in the metro area. The long distance links may be managed by the same technology. And they decided that they wanted to go everywhere. And there they found a problem called Global Connectivity, meaning that you had multiple operators between the end points. It was at that stage that the MEF was at the end of 2010. Earlier this year, on February 23, 2012, the MEF introduced Carrier Ethernet 2.0. This will be an area of interest for the next two years.

Russell: Who were some of the leading people involved with this?

Danthine: Bob Metcalfe, the Ethernet inventor, Nan Chen, the Chairman of the MEF and Stan Hubbard. So as we have finished, we can make a grand tour of the campus if you want to have a general view of the University.

Russell: Thank you very much for your time.

<Interview ends>