



SNT

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Interdisciplinary Centre
for Security, Reliability and Trust

Annual Report 2010



UNIVERSITÉ DU
LUXEMBOURG



SnT is an internationally leading research facility that together with external partners establishes Luxembourg as a European centre of excellence and innovation for secure, reliable, and trustworthy information and communications technologies (ICT). To create great impact, SnT follows an interdisciplinary research approach, taking not only technical aspects into account but also addressing business, human, and regulatory issues.

Editorial



Prof. Dr. Björn Ottersten



Prof. Dr. Thomas Engel

Early 2009, the University of Luxembourg (UL) created its first research centre – the Interdisciplinary Centre for Security, Reliability and Trust (SnT) to spearhead one of the university’s priority areas. The creation of SnT should be seen in the context of the government’s strategy to raise the competitiveness of Luxembourg. Large infrastructure investments provide a very attractive environment for the development of high value ICT services and applications in Luxembourg. Security, reliability and trust are keywords associated with these services. SnT’s goal is to fuel the economy with ideas and people that will assist in building this country’s future.

SnT aims to achieve high impact and excellence by collaborating with external partners such as industries, government bodies, institutions, and international actors. It brings together researchers from external partners and the UL faculties to carry out research and PhD education in Security, Reliability and Trust. Research activities are carried out through interdisciplinary research platforms targeting key areas of strategic importance for the region: communication and network infrastructures, services and content, and enterprise security.

In the SnT Partnership Programme, members contribute to the Centre at all levels, in the governance with representation on the Advisory Board, in the strategy and planning on the Industrial Advisory Board and in the operations with participation in research projects. We are proud to have seven partners in the programme. Together with other sources of competitive funding, their contributions amount to 50% of the SnT turnover in 2011. You will find the partnership activities highlighted throughout the report.

We are pleased to present the Annual Report 2010 which provides a brief overview of our achievements. Only a small number of our research activities can be highlighted, please visit our website for additional information.

Prof. Dr. Björn Ottersten
Director

Two years at SnT – and already there have been plenty of findings. Within a short period of time excellent scientific results have been produced. The list of publications from 2010 speaks for itself: 80 co-workers by the end of 2010 and 88 releases! Naturally it isn’t quantity that counts but above all quality. Five Best Paper Awards at conferences like the International Conference on Autonomous Infrastructure, Management and Security (AIMS) or the International Conference on Network and System Security (NSS) speak for themselves. SnT is an attractive platform for collaborative scientific research projects as is illustrated by the fact that several faculty members have joined from all University Faculties. We have also been able to obtain significant funds from several national and European sources like FNR and ESA and have thus managed to achieve a favourable mix of funding instruments.

We can only develop this scientific performance in the long run if we are strategically well connected – and work on the truly important future issues. And we feel that we have chosen the right path: Our partnership programme has been very well accepted. The benefit is on both sides: SnT gets a closer look on the real world; we learn which issues are important to the industry and see in which fields we can achieve excellent research progress. On the other hand, we help the industry work on new topics from a basic research perspective and on the basis of scientific findings they then develop innovative business models and products.

But why don’t you see for yourself: You will find various articles on ongoing research in this Annual Report 2010 that we are proud and happy to present to you.

Prof. Dr. Thomas Engel
Vice-director

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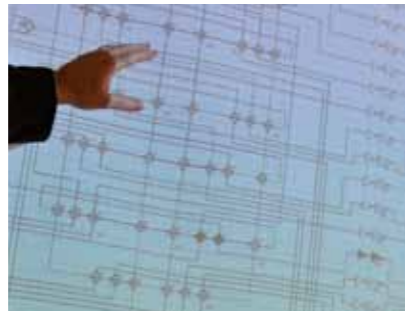


2D/3D image fusion

Frederic Garcia and Researcher Djamilia Aouada designed algorithms to fuse 2D and 3D images in real-time captured by a hybrid 2D/3D camera. "Our software combines the high resolution of a two-dimensional image with the depth of a three-dimensional one", explains Frederic Garcia. This is of great importance for example for the development of surveillance cameras that have to provide high quality pictures even in bad lighting – like at Luxembourg airport. The project „Multi Sensor Fusion“ is part of SnT's partnership programme with IEE, a global leader in automotive safety sensing systems for occupant detection and classification. Djamilia Aouada says: „IEE gave us access to raw camera data. This is the precondition for a fusion system to perform in real-time – and this is unique worldwide in the design of this technology."

Reachable through space at any time

SnT and SES conduct joint research to further develop satellite based communication.



The screen stays dark. No news, no entertainment, no TV at all. Only a line of text running through the image: "Dear viewer, it is our constant endeavour to improve our services for you. Therefore, we are currently checking and maintaining the technical systems of our television satellites. For this, we need to turn off all devices for five days. We thank you for your understanding." An unimaginable scenario! The world we live in depends on uninterrupted communication. A daylong TV or even internet or telephone blackout would lead to a break down in the economy and panic in the population.

What we are daily informed of – an around the clock constant offer of communication services – should in no way be taken for granted, especially in satellite based broadcasting: "Satellites run in an exceedingly inhospitable environment", says Daniel Arapoglou, a scientist at SnT: "They are faced with extremely high or low temperatures and radiation bombardment from space." It is of great importance that satellite operators are constantly aware of the state the technology is in. "We need to intervene in time when complications due to equipment aging start to show", says Arapoglou, "Also, we can make sure they run continuously – without expensive, emergency back-up systems or taking satellites out of service after twelve to 15 years because operational safety is no longer guaranteed."

Broadcast TV, the main satellite communication service, is facing competition from new distribution means. Satellite broadcasting will evolve to satellite communication networks carrying not only TV but Internet connectivity to fixed and mobile users, this is a major challenge: "Companies that operate satellites, and manage to early identify new system architectures and key technologies, are able to acquire an important competitive advantage", says Professor Björn Ottersten, Director at SnT, and adds confidently: "SnT is scientifically dealing with this and conducts cutting edge research."

Within its priority research field 'satellite systems', SnT engaged in a strategic cooperation with SES last year, one of the world leading satellite operators. SES runs 40 geostationary satellites in space and offers its services in satellite based communication in every continent. "We are well aware that we need a constant supply of new impulses out of research to stay competitive and break into new business fields", Martin Halliwell, President of SES Engineering, explains this cooperation: "Essential issues are software and artificial intelligence. And therefore these are also the focus of the projects we work on with SnT." In one project, SnT is accordingly designing algorithms and software that continuously monitors the functional operation of a communication satellite.

"But SnT also helps us optimally prepare the next generation satellites for work in space and for servicing our clients", Gerhard Bethscheider, CEO at SES-Astra Techcom adds. These satellites, he explains, are way more complicated than those in use up-to-date. "For the satellites that are currently in orbit, we could still make use of diagrams to calculate their load capacity", but these times are over now, says Bethscheider, "Currently a common SnT and SES Ph.D.-candidate, Apostolos Stathakis, is working on optimization algorithms and simulations that will allow



Ph.D.-Candidate at SnT and SES: Apostolos Stathakis (left) together with Gianluigi Morelli, Apostolos' advisor at SES.

optimal exploitation and reconfiguration of the communication capacity of increasingly complex satellites – so that we can intelligently meet the steadily increasing current and future demands of our clients."

What kind of demands are we talking about? Don't we usually feel well enough connected? "This may be true in large cities", scientist Arapoglou explains, "But there are many areas, also in Europe, in which you will quickly land in a dead spot if you use a mobile device like a smart phone that only communicates with conventional transceivers of mobile network operators." To change this, SnT is working on the so-called MIMO project with SES. MIMO is short for Multiple Input/Multiple Output and has revolutionized terrestrial communication. It supplies mobile devices with high quality signals: Both sender and

receiver, such as mobile phones, each dispose of several antennae, via which they exchange different kind of signals. These signals carry the same message at the same point of time – but depending on the surroundings in which the mobile receiver resides – arrive in differing levels of quality. "Except for improving the data rate, MIMO also protects reception in harsh areas like in a tunnel or an urban canyon", says Arapoglou, "therefore the mobile device is always adequately connected with the network." The challenge now is to adapt this technology to satellite based communication.

Director of SnT, Björn Ottersten, has already noticed first results that the strategic approach he has chosen for his institute has brought along: "To solve such a complex problem, you need excellent scientific expertise, you need to be aware

of legal guidelines, and properly understand the companies' needs." He is sure that SnT is brilliantly equipped for this: Funded by the European Space Agency (ESA) for this activity, the scientists at SnT are approaching the problem first theoretically, developing models and simulations to make MIMO-technology usable for satellite based communication. SES brings in the system scenarios as well as the needs of the users of this technology. In this way, the partner institutions can leverage their research and application-oriented approaches – and thus work out an enormous knowledge advantage for SES and of course Luxembourg. Ottersten: "This is scientifically fascinating, economically valuable and shines brilliantly well beyond the borders of Luxembourg."

First European Summit on the Future Internet



As an academic research institute, SnT naturally stands for scientific exchange and scientific discussion. Its aspirations, however, go further than that: SnT wishes to offer stakeholders from industry, politics and science a platform for information exchange and opinion forming concerning socially relevant issues.



Minister François Biltgen opening the First European Summit on Future Internet

On the second day, technical perspectives of Internet development were put on the plate. Speakers and discussion participants worked out how to develop Smart Internet enabled Infrastructures capable of overcoming, cost and performance wise, today's dumb infrastructures. Energy and transport matters will benefit just as will the health and entertainment sectors – that is the unanimous opinion. This will not only be based on the fact that the economy will increasingly use the Internet for conventional business processes. The development of the Internet technology itself will offer opportunities for new business models with innovative service architectures and search engines that take into account media, location and context as well as new security and privacy paradigms.

The First European Summit on Future Internet held in June 2010 is a very good illustration of the role of SNT as a catalyser for change. At the centre of the debate was the question as to how to prepare for a Future Internet that can cope with the demands for generalized mobility, improved security, reliability and trust, the delivery of time critical and high bandwidth applications, as well as the emergence of an Internet of Things.

Education and Research, welcomed the guests at the Chambre of Commerce, the political agenda was introduced: The European Commission Directorate General on Information Society and Media, represented by Mario Campolargo, Director of Future and Emerging Technologies, presented the European Commission's strategy to future internet development in the European Union. Focus points were the innovative potential of the Internet and its role as both growth and competition factor.



"The First European Summit on the Future Internet was a good platform to discuss strategies and policies as well as technical options and new service concepts", Björn Ottersten, Director of SnT, concluded. He further stated: "It gave important impulses on how we can realize these ideas through collaborative research and development efforts and open test beds on a European scale, especially in view of the emerging Future Internet Public Private Partnerships." Reason enough for SnT to continue the series with the 2nd European Summit on the Future Internet in June 2011.



250 guests arrived at the two-day event that SnT organized jointly with the Luxembourg Chamber of Commerce, Lux Innovation and Luxembourg for ICT. After François Biltgen, the Luxembourg Minister for Higher

Education and Research, welcomed the guests at the Chambre of Commerce, the political agenda was introduced: The European Commission Directorate General on Information Society and Media, represented by Mario Campolargo, Director of Future and Emerging Technologies, presented the European Commission's strategy to future internet development in the European Union. Focus points were the innovative potential of the Internet and its role as both growth and competition factor.

The fastest way through road traffic

A framework agreement between SnT and P&T aims to set groundwork for traffic revolution



Jean-Marie Spaus, P&T Luxembourg

Thursday, March 3rd, quarter to nine am. Luxembourg at Konrad Adenauer Boulevard. Outside the European School in Luxembourg crowds are thronging. Cars are waiting in long lines ahead of traffic lights, some merge to the side of the road, students exit the vehicles, following drivers push into opening gaps, others venture back out into traffic. It all happens at an excruciatingly slow pace. Meanwhile, time flies by: just about 15 minutes left to get to that meeting.

Traffic situations like these can be found on weekday mornings at numerous crossroads in Luxembourg. The City of Luxembourg with its population of barely 90.000 may not be particularly big, says Thomas Engel, vice-director at SnT: "However, due to the many commuters from France, Germany and Belgium, rush hour traffic on our streets is comparable to that of major cities like Brussels or Berlin." And Engel adds: "At SnT we are intensively working at reducing these traffic jams!"

"Vehicular Networks" is the title of the framework agreement that SnT has signed with P&T, the leading Telecom and Postal Service provider in Luxembourg. This contract states that both institutions, together with other academic partners, will put into practice scientific projects to analyse and improve traffic flows. Engel is head researcher of the initiative. "We have got the scientific know-how", he says, and the vice-president of P&T, Jean-Marie Spaus conveys: "This adds ideally to P&T with its great infrastructure – its car pool, and mobile and land-

line networks for data transmission." Modern communication tools play a key part in this undertaking.

Traffic flows are highly complex. "We want to understand this complexity to influence traffic flows more efficiently", says Engel. To this end, he is working with his team and partners on three levels: calculation, simulation and practice. Calculating complex flows like street traffic has become easier to manage in the last few years thanks to the so-called packet theory. Here, traffic isn't considered a homogeneous mass or liquid, but is divided into packets: "This is how modern telecommunication works", Engel explains. For example skype users are no longer physically connected to each other by a copper cable carrying the data. In fact, adequate software divides the information into many little data packets that, independently from one another, search for the shortest and fastest way through the network to get to the receiver. There, a counterpart to the disassembling software puts the data packets back into their right order – and makes them comprehensible to the skype partner.

"We are currently adapting mathematical models that are based on this process to the more complex problem of road traffic", says Thomas Engel. "For that, we have excellent partners like the Network Research Lab at the University of California in Los Angeles as well as FNR's research tools." The self-addressed assignment may be a "thick board we are drilling", Engel continues – but worthwhile: "SnT's strategy isn't to conduct product development, but to develop a basis for entirely new product classes through scientific findings." This is the only way to build a true competitive advantage – Engel's credo. After the model calculation now comes the simulation. And we are not talking about a model highway – again, it's about computers: In their programmes, cars are sent through pathways accord-

ing to the packet theory, and scientists study how the global traffic situation changes when certain parameters are altered. What happens for example when vehicles are notified in due time of another car ahead, slightly braking? How many drivers need to be included in the information flow in order for a positive effect to set in?

After that we jump to the real-life experiments. "Vehicular Networks" is well equipped for this stage due to P&T and the advantageous location that is Luxembourg, as Jean-Marie Spaus explains: "The results of calculations and simulations at SnT can be verified using the postal service's car pool, of which individual parts are connected by GPS and mobile networks or the Luxembourg wifi-net Hotcity." When switching from theory to reality, the need to consider personal rights and privacy is a top priority for both Engel and Spaus. Engel asserts: "The systems we are talking about need to be designed in a way that individuals voluntarily offer data that improves the traffic system, but that do not allow to draw conclusions on the behaviour of the individual." That is an enormous challenge, technically and communicatively. "But if we manage, we can revolutionize traffic", says Engel.



Thomas Engel, SnT

What would such a revolution look like, Mr Engel? "Do you enjoy playing on your smartphone?" "Of course, when there's an ambitious high score to reach." Engel is excited: "Then you are our ideal test subject!" Because intelligent traffic



management of the future could follow a playful approach: "In the morning on your way to work you type into your phone whether you are in an extreme hurry, or if you're driving at a normal speed to work, or maybe you might even find time to comfortably cruise the streets that day."

And then begins the Linden Dollar game, the virtual currency in Second Life in which mobile phones communicate with cars just like vehicles on the street and their technical components do among each other: A number of drivers and players have fed their phones with information on how badly in a hurry they are. The technology that surrounds them in their cars and phones now communicates directly over mobile networks, landlines or even via satellites, in case terrestrial connectivity isn't available. Drivers are given intelligent and risk free navigation recommendations. Engel illustrates: „Suppose you are in a hurry. Your surrounding drivers are notified unobtrusively – and make way for you. On the highway, cars veer to the right to let you fly by, and at the construction site you pass by everyone in the fast lane and softly get back in lane at the very end."

"Sounds great – but how much will it cost me?" "Linden dollars, so game money. Today you pay because you're in a hurry, tomorrow you make money by letting

others go ahead. The safest and most considerate driver cracks the high score." And in addition traffic becomes smoother, says Engel, because positive effects become apparent in the entire system when only five to ten percent of all drivers participate in the game – thus the considerate and foresighted drivers.

Before this vision can become reality, a long road still lays ahead of researchers and product manufacturers, Engel warns: "First we not only need to understand what happens on our streets. Right now, the existing technical components aren't able to communicate with each other yet in a way that is necessary for such a scenario." For example, while mobile phones and vehicles need to communicate, in the car's interior also, navigation system and tachometer need to speak the same language, as well as distance sensors and ABS. Jean-Marie Spaus describes the economy's point of view: "We have reached a whole new level of data exchange, for which the industry has only just begun developing standards. The important issue here is: safety first. Until the ideas discussed here can be put into practice and function in their entirety – we yet have much to do." "And still", Engel adds, "In ten years you will arrive at our meeting in time – because drivers let you pass by, without you even noticing."

Secret vote without list of candidates

Peter Ryan's team is studying new, secure vote counting systems at SnT



Peter Ryan researches on secure vote counting systems

Europe last voted in June 2009. That was the first time since the EU enlargement that citizens from 27 member states could determine who would represent them in the European Parliament. Even though this was a historic event, voter participation was less than 43 percent in the EU, with significant differences however between certain countries: Malta and Italy were top-ranked among those without compulsory voting – about three out of five citizens casted a ballot. In Lithuania and Slovakia on the other hand, only every fifth person called upon their right to vote.

People will vote if they feel that their vote will make a difference. That is they first need to be assured that their vote will be accurately counted. In western democracies is of course virtually always the case because the political system is stable and the legality of elections is effectively monitored. Psychologically, this is nevertheless an important signal. This is especially true in crisis regions, where electoral fraud and manipulation have to be considered.

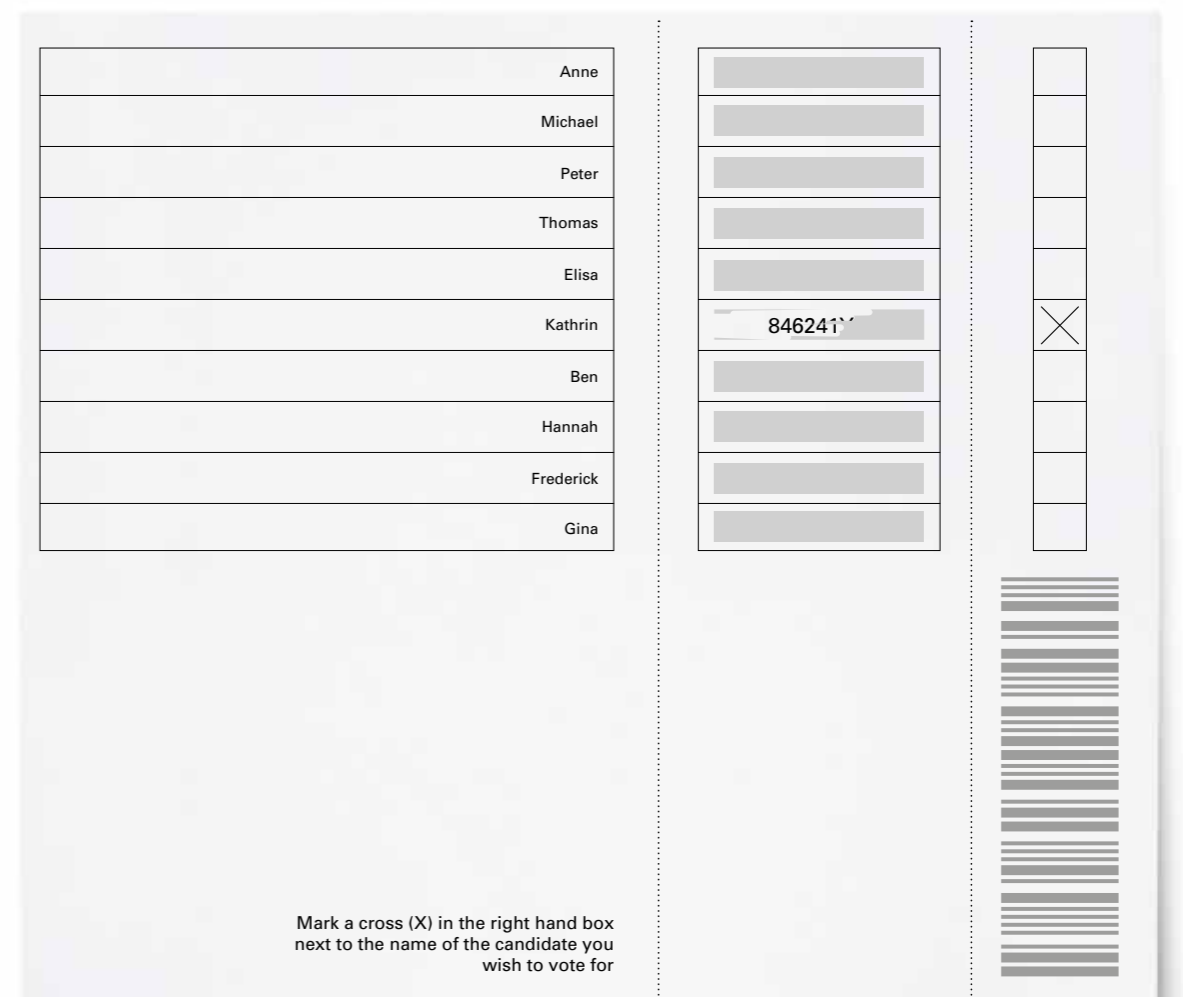
"Our research interest is on electronic voting systems, where citizens conventionally cast a paper ballot at a polling station and can still be sure a moment later that their vote was counted," says Professor Peter Ryan, faculty member at the University of Luxembourg and researcher at SnT. Most people, he adds, think electronic voting is done online.

This would however be an even more complicated voting system: "How can you guarantee that no spouse or boss was looking over the shoulder as you cast your vote?"

So what it comes down to is a vote casted at the polling station and the assurance of it being properly counted. How can this be done? "At the basis lay highly complex, mathematical ciphers that anonymize, transfer and evaluate the data", Ryan explains and then illustrates with an example: At the polling station, the voter is handed over his ballot as usual. The ticket consists of three vertical columns. On the left are the names of the candidates or the parties, in the middle column there's a number sequence behind each candidate's name – shaded at first by a grey coating like on a scratch card – and on the right you'll find the circles to be checked. The latter column can be sectioned off of the ballot at perforation und deposited in the ballot box.

Yes, it is true: You only hand in one ticket with your vote – without the list of candidate names. Because there is something more that is different than with conventional ballots: The candidates' names are listed in differing orders an each ballot. This order is random. Utter bewilderment now obviously sets in, because how can anybody retrace at whom the vote was directed? "The trick is that every ballot carries a barcode", Ryan unravels the mystery: The order of the candidates' names is hidden in the code. When the votes are counted, the code is scanned and both code and vote are sent to the evaluation centre. There, the bar code is deciphered, so that names and vote correspond again and the vote is counted.

How does the voter know that their vote was properly counted? This is where the middle column on the ticket comes into play: The voting committee is given a computer-generated number sequence once the vote is counted – once names



An example of a ballot developed at SnT

and vote correspond and are taken into consideration. This number sequence is also transmitted to the voter at the polling station. The voter then scratches off the grey coating behind the name of the candidate he chose – if it is the correct number sequence, regularity has been assured, the vote was properly counted.

"The ciphers behind this system are highly complex", Ryan reckons, "We have to guarantee security in the correct data transfer and simultaneously make sure no conclusions can be drawn to who the voter is." Ryan is confident that his team is right on track: "We have already de-

signed prototypes that are used for instance in student parliament elections. On the basis of feedback from these trials, we will be able to improve the system so that it will also be usable at political elections." Until then however, it is still a rather long way. "Here is where we benefit from SnT's interdisciplinarity", says Ryan, "Naturally we must also understand and consider legal, psychological and communicative aspects of counting systems at elections. In the surroundings of SnT we will be successful at this." And finally, the new counting system then needs to be made palatable to the political actors.

15 milliseconds to becoming more intelligent than a hacker

SnT studies how cyber crime works and how it can be fought

Radu State is fascinated by the technology of the internet. Enthusiasm for extremely specialized software and curiosity regarding further developments lay the basis for his work as a scientist at SnT. People also fascinate him, just as much as technology does, and they regularly manage to surprise him: For example those two hackers that visited an SnT honeypot a while ago. Honeypots are computers that researchers make available on the internet to trap hackers and observe their criminal doings, then draw conclusions on how to fight off and undermine attacks from cyber space in future. "So there were two hackers at our honeypot. Highly professional – they had excellent knowledge of the technology. They knew what they were doing and were chatting freely while doing so. Suddenly one of them said: 'Hey, I've got to go, my mom just got home and wants me to do my homework.' Those were twelve-year-olds we had on the hook!"

The internet connects, encourages exchange, trading and cash flow. And it attracts criminals. This finding is not a new one. However, day to day, internet pirates use new methods, worms, botnets and malware, which can cause tremendous damage. In addition, the number and effectiveness of the attacks steadily increase: "The internet is huge, there are many hackers out there with lots of time", says Radu State, "we on the other hand are much smaller in number and have no time. Therefore we need to design intelligent systems that can avoid much damage at once." The Luxembourg Ministry of Economy and Foreign Trade also believes this, and thus entered a research framework agreement with SnT on combating cyber crime. The goal: Luxembourg is to be a reliable partner also in future with a trustworthy and secure IT-space.

In order to reach this goal, one has to find out which patterns cyber crime follows, and be able to adjust to the rapid changes extremely quickly. SnT is running several projects in this area, one of them being the honeypot project. A particularity of the latter is the intelligent SnT honeypot: Most of these, purposefully opened gateways for hackers are easily identified as traps – attacks are omitted. Some even allow intruders to dramatically misuse the computer for their own aims, with disastrous consequences. "In both cases, we won't reach a higher level of security", says State, "We have therefore designed an intelligent machine that lures hackers and responds in a flexible way to attacks. Flexibility is a challenge for hackers, they get stuck for a while and simultaneously we learn a great deal about them."

Flexibility is given 15 milliseconds of time. In this very short moment our honeypot has to analyse the form of attack and figure out how to respond. Does it offer information that will help the hacker a little in their endeavour? Does it give fake information and set the attacker on the wrong path? Or does it put on a human mask? *Human mask?* "Our computer can swear in different languages", Radu State explains. "We ourselves didn't think it possible – but if there's a person sitting in front of one's screen and the attack isn't solely computer generated, then in 70 percent of all cases somebody swears back at us. What we gain here is: We know with high certainty where the hacker is seated. Even if they got hold of a computer from the other end of the world for their schemes."

Just as important as studying cyber criminals' techniques is to follow what happens on the meta-level of the internet. It's not sufficient to accurately know



Martin Hlavác at the server farm

a certain type of worms if you don't discover in time where they are massively spreading. To this end, SnT has designed an analysis tool especially for Luxembourg: A set of greatly reduced computers connected to a public network and sending each other control message. These messages are part of the online flow without bothering with the content. "From the type of signals and their time of arrival at the partner computers in our set, we can deduce the characteristics of data stream in the network by using a specially designed software", says Radu State, "Is everything as usual or are there nodes at which abnormalities can be observed that might indicate criminal activity? There, network operator can have a closer look and provide remedy."

Martin Hlavác, also an SnT-scientist, is aiming to reach the same goal with a technically much more intricate system. It's supposed to unfold its effects beyond the borders of Luxembourg and results

from collaboration with the Luxembourg Ministry of Economy and Foreign Trade. With a small server station, Hlavác wants to turn Luxembourg into a surveillance centre for domain name systems (DNS). "DNS is the internet's phonebook", Hlavác describes the system, "in it, real names for websites like uni.lu are linked to the IP-addresses of the computers that host these sites and other services." Phishing site operators misuse the DNS to their own purposes: They recreate websites from e.g. banks to gain access to passwords and clients' personal data.

The data thieves animate these clients via email to follow a link that supposedly leads to the bank's homepage, in reality though brings them to a phishing site where they are asked to enter their password, for instance. Phishing websites are situated on many squatted computers – whose owners know nothing of it – and after links are clicked, the DNS forwards the IPs of these externally controlled

computers. "With our servers we will analyse anonymous DNS-answers and with this, we can recognize anomalies in the system quickly and reliably", says Hlavác. For example, an anomaly could be a massive issuing of different IPs – those of the squatted computers – for a certain, so-called fast flux, hostname – that of the fake bank. For analyses of this kind, the cooperation of SnT with network internet service providers is being planned. The latter give SnT anonymized DNS data, where it is then evaluated in a large, common data pool: „The combination of the huge mass of information from different sources makes it impossible to draw conclusions on individual computers, or even individual data providers", says Hlavác.

This is common to all SnT projects: "The single data record of an individual computer doesn't interest us in the least", Hlavác explains. The big challenge is rather to design an analysis method that gives an overview and shows up patterns quickly, which in individual cases lead to a problem. Because only then can you intervene timely, prevent worse problems – and create security, reliability and trust in the net.

Becoming impossible to overlook

Interview with Björn Ottersten,
Director of SnT



Prof Ottersten, SnT is now about two years old. More than 70 people work here. The Centre has engaged in numerous industrial collaborations, you have acquired over 50 percent of the budget from external sources. Now let's think five years ahead – what will the SnT look like in the year 2016?

Ottersten: My vision for SnT in five years time is one with even stronger interdisciplinary networks and an expanded partnership programme with national and international partners. We will be involved in important EU projects and our first successful spin-off companies will have been launched. To carry this load, we will have about 200 employees in 2016.

And what are the prerequisites for this?

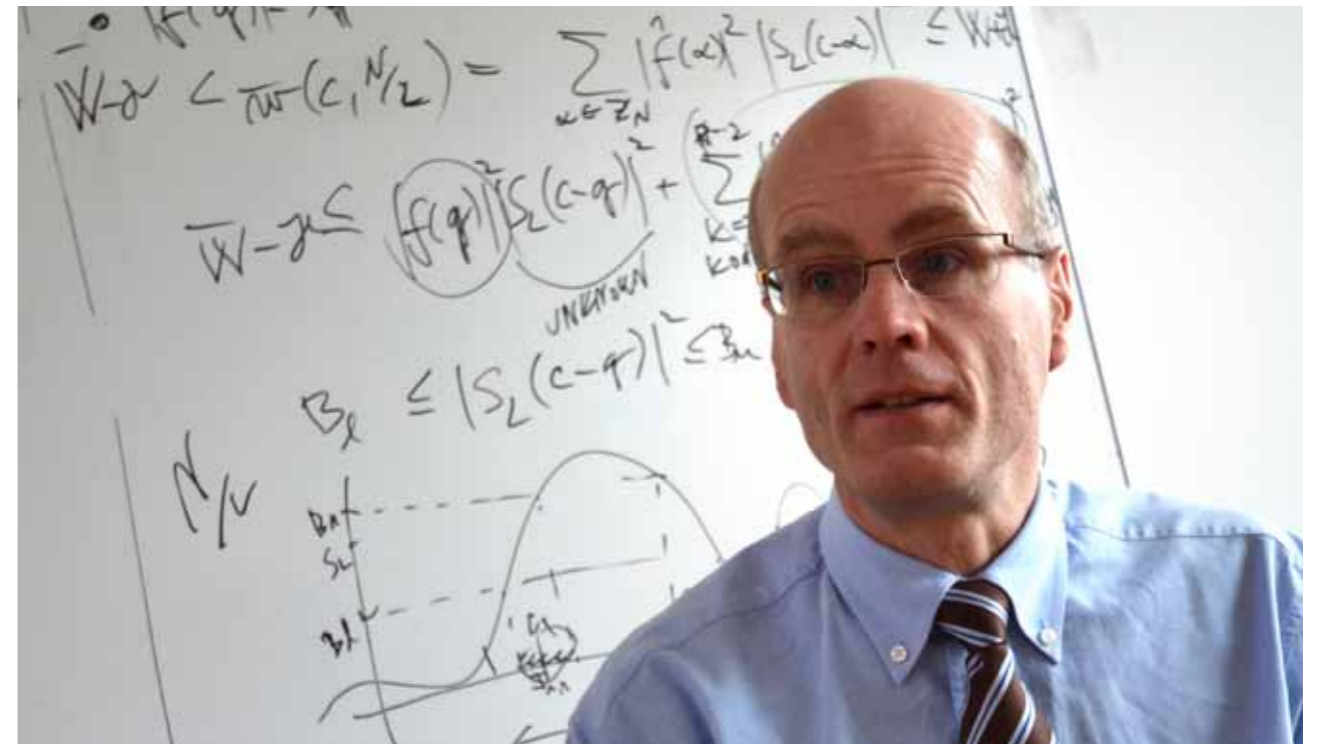
Look back to the beginnings of SnT and its location and you will find that this vision is realistic. Take the example of communication infrastructures: 15 years ago, Luxembourg was poorly connected to the world via the Internet. When suddenly it became clear that financial services would need these to be able to function. The government put a strategy in place and pursued to implement it quickly.

Luxembourg caught up at stupendous speed and today presents a perfect example for optimal technical networking. And this isn't all – security in data transfer and the legal framework for it have played a big role from the start. We've got the

necessary know-how because Luxembourg is an important financial centre, which we integrate systematically into our research activities here at SnT. We combine IT knowledge with psychology, law, economics and engineering, taking a holistic approach to this research field will set us apart and create impact well beyond the scientific community.

You want to expand the partnership programme with national and international partners. Why does SnT have such a programme?

This stems from SnT's genesis. The scientific location Luxembourg is still pretty young; the University was only founded in 2003. With a new focus on science, Luxembourg wants to support its economic diversification and break into new economic sectors besides the financial services. In this process the Interdisciplinary Centres of the University of Luxembourg – so far these are SnT and LCSB – are key players. Both work in concisely defined, economically promising research fields: At SnT these are communication and network structures, media intense industry and enterprise security.



And this is where the SnT partnership programme comes in?

Yes, because we know that the economy and society have a great interest in measurably improving security and reliability in these research fields. Both factors are prerequisites for trust in economic life. Additionally, they open up completely new economic fields of activity: Companies can use the new, secure and reliable applications themselves or offer them as a service to their clients. In both ways – as basis for personal economic activities and as key for new business models – security and trust constitute the foundation for our partnership programme: SnT offers the scientific know-how and campaigns for additional research funds, while the businesses bring in economically relevant, scientific questions and improve their market position.

SnT as an R&D department of companies?

No, SnT is an academic institution. We are interested in the mid- to long-term perspective – for competition reasons also: An application that was designed within six months can easily be imitated. But when there's basic research behind it, then product piracy becomes way more difficult. The companies that work with us acquire a valuable advance in knowledge or they may even find themselves in a position where they can basically design a new product. The knowledge advantage can also lead to SnT spin-offs, of which I hope, as I have mentioned before, that the first ones will be launched successfully within five years.

Now we have spoken a lot about science and its role in the economy, Prof Ottersten. So what is a scientist's major goal at SnT?

A goal that I, personally, find most relevant? I want to put SnT and thus Luxembourg on the international scientific map and make it impossible to overlook!

A booster for public private partnerships

SnT's Partnership Programme

SnT is committed to fostering the production of innovative ideas, increasing the depth and breadth of the competence, and facilitating research in collaboration with established partners as well as new start-ups in the ICT industry.

Through the partnership programme, partners contribute to and influence the development of SnT at all levels. The partners have representation on the SnT Board where the Centre strategy is developed. The Industrial Advisory Board supports the strategy and operations of SnT. Research is conducted jointly in partnered projects where SnT and partners contribute know-how and resources to achieve common goals.

Members of the Partnership Programme



BCEE is Luxembourg's state savings bank providing all the functions of a commercial bank, including retail banking and private banking. Research interests include access control policies and cloud computing, role-based access control policies, address maintainability problems with roles, agents, resources and permissions.



IEE is a global leader in automotive safety sensing systems for occupant detection and classification. The company also provides people and object sensing solutions that enhance building safety, security and management. IEE operates worldwide and employs about 1,400 people. As a

partner, IEE supports a multi-sensor fusion laboratory providing an experimentally driven research programme in 2D-3D sensor fusion, multi-view camera fusion, detection, classification, and recognition.



itrust Consulting advises customers from public, financial, and private sector in protecting their information against divulgence, manipulations and unavailability. In the context of location-based services (accessible with a mobile device that make use of the location of the device to supply functionalities), the research aims to provide a high quality level of assurance in the location information from GPS and Galileo, while protecting location data owners from intrusions into their privacy.



The Ministry of Economy and Foreign Trade in Luxembourg actively promotes security and trust in ICT systems and services building on the country's reputation of delivering trustworthy services. Research projects include network security, malware and botnet detection, intrusion detection, digital forensics, network data collection and analysis.



P&T Luxembourg is the incumbent national telecom operator with fixed, mobile and wifi networks. P&T Luxembourg has introduced an integrated mobile telecommunication solution for the development of automotive telematic services in Europe for PSA Peugeot Citroën. This reflects

on the research interests of the partnership; vehicular networks, development of applications and services for vehicular networks, human machine interaction, open platforms, testing, verification, and validation of software systems.



Founded as *Société Européenne des Satellites (SES)* in 1985, it is one of the world's leading providers of satellite communication and transmission services. SES has a fleet of some 40 geostationary satellites in 26 orbital positions serving all continents. The research programme comprises applications and services meeting innovation, cost efficiency requirements while secure, reliable, and trustworthy satellite hybrid networks create an interconnected communication environment in space and with terrestrial networks, transmission, and reception technologies through advance pre-coding and receiver technologies, and legal and regulatory challenges, liability and risk, spectrum regulation and competition law.



As part of Belgacom, Telindus Luxembourg provides ICT services and solutions to the corporate and public sector. Telindus operates and deploys mobile and wifi networks in the country. The research programme addresses mobile and wifi networks, location and context aware services, security and reliability in heterogenous networks, mobile network offloading.

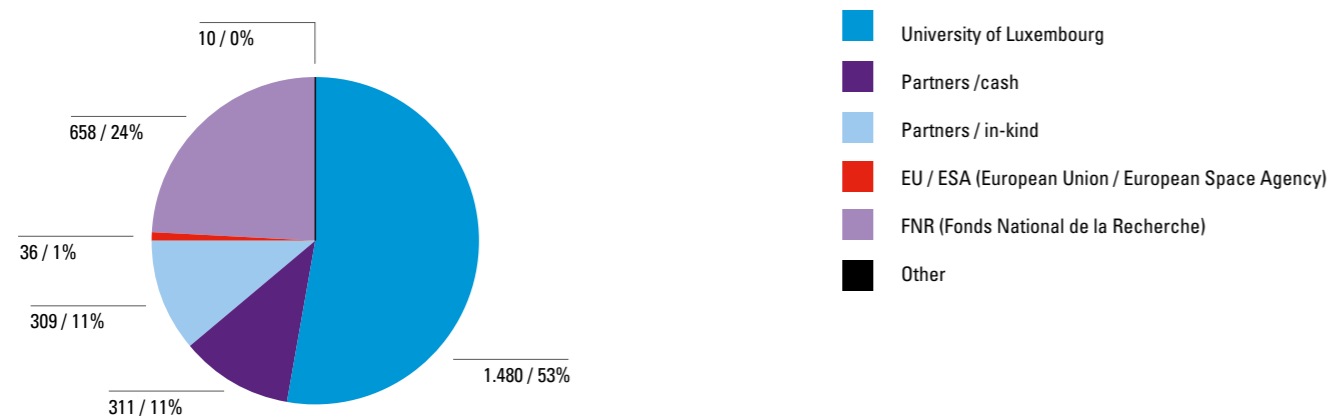


Hotcity is the public wifi network in the city of Luxembourg. Yves Neisius pondered how wifi networks could be integrated into hotcity: "If we succeed, then the public network becomes denser and performance increases," says Neisius, "In the first year of my doctoral thesis – in cooperation with SnT and Telindus – I designed the prototype of a router, like the type you'll find in private households and that can easily be integrated into the hotcity net." In doing so, we need to consider many legal and security aspects in data transfer, which Yves Neisius is currently dealing with at Telindus. Telindus Luxembourg is part of Belgacom and provides ICT services and solutions to the corporate and public sector.

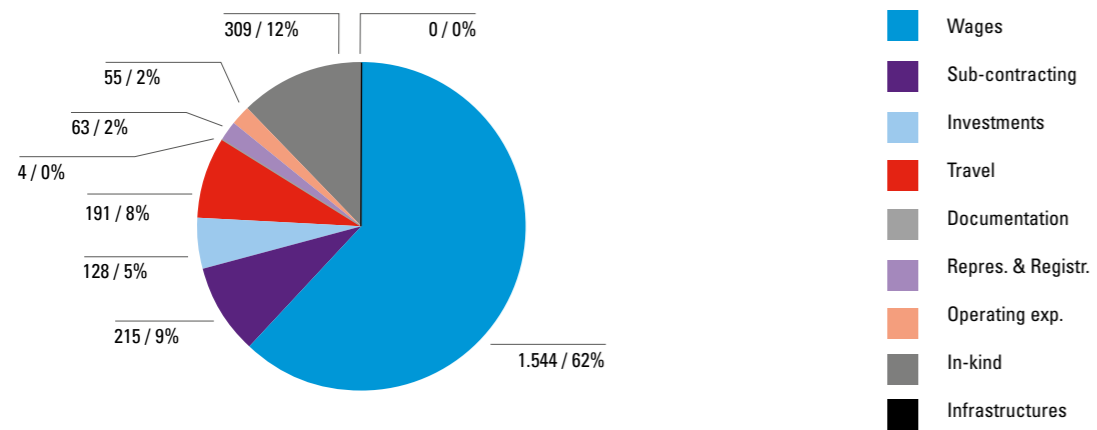
How to integrate private routers into public networks

Financial data

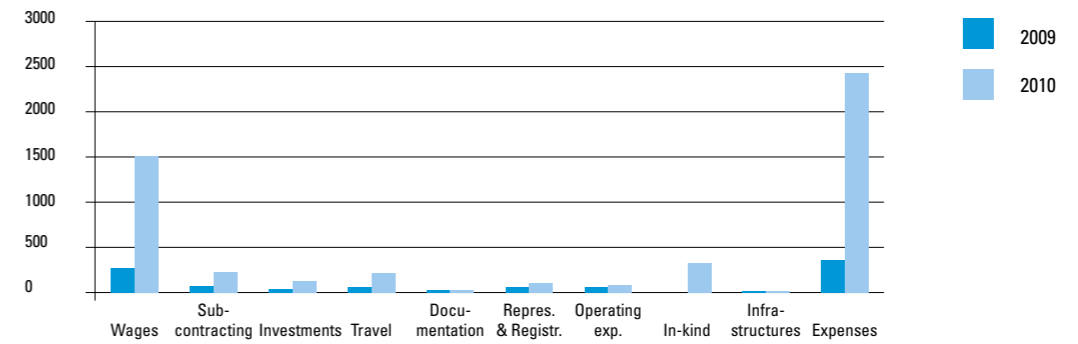
2010 SnT income (in kEUR)



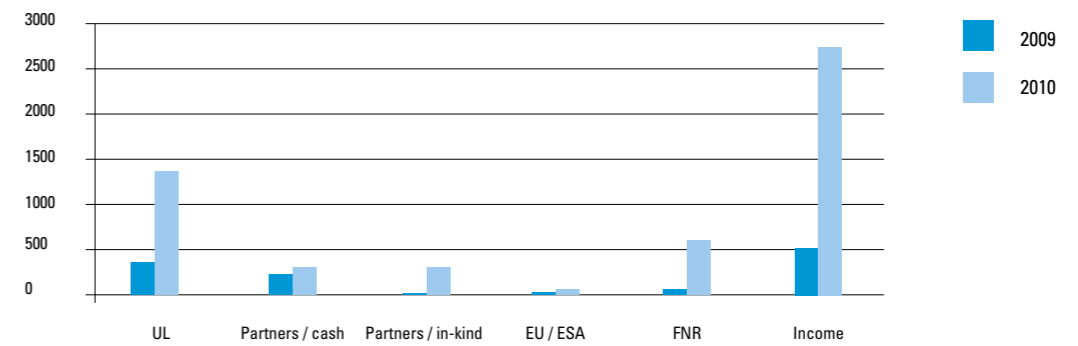
2010 SnT expenses (in kEUR)



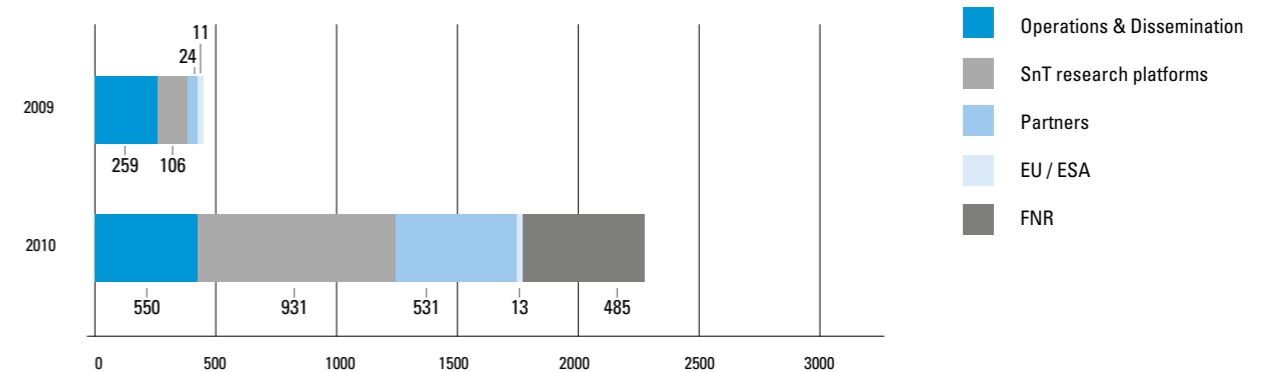
SnT 2009 – 2010 expenses per category (in kEUR)



SnT 2009 – 2010 income per source (in kEUR)



SnT 2009 – 2010 expenses per funding source (in kEUR)



Awards, PhD degrees and events

International Awards

Andriy Panchenko was awarded the KuVS prize for the best dissertation 2010 in Germany for his thesis *"Anonymous Communication in the Age of the Internet"*.

Shaonan Wang, Radu State, Mohamed Ourdane and Thomas Engel received the Best Paper Award at the 4th International Conference on Autonomous Infrastructure (AIMS 2010) for *Mining NetFlow Records for Critical Network Activities, Mechanisms for Autonomous Management of Networks and Services*

Yves Le Traon, Jacques Simonin, Emmanuel Bertin and Jean-Marc Jézéquel received the Best Paper Award at The Fifth International Conference on Software Engineering Advances (ICSEA 2010) for Business and Information System Alignment: *A Formal Solution for Telecom Services*

Yves Le Traon, Philippe Dhaussy, Pierre-Yves Pillain, Stephen Creff and Amine Raji received the Best Paper Award at Approches Formelles dans l'Assistance de Développement Logiciel (AFADL, 2010) for *Contribution à la formalisation de contextes et d'exigences pour la validation formelle de logiciels embarqués*.

Cynthia Wagner, Gérard Wagener, Radu State, Alexandre Dulaunoy, and Thomas Engel received the Best Paper Award at the 4th International Conference on Network and System Security (NSS 2010) for *Breaking Tor Anonymity with Game Theory and Data Mining*.

Björn Ottersten was awarded the EUR-ASIP Meritorious Service Award

Dzimitry Kliazovich, Pascal Bouvry, and Samee U. Khan received the Best Paper Award at ACM/IEEE International Conference on Green Computing and Communications (GreenCom) for *DENS: Data Center Energy-Efficient Network-Aware Scheduling*.

National Research Awards

SnT and P&T awarded the Best ICT Alliance of the Year

PhD Degrees

Michael Noll *"Understanding and Leveraging the Social Web for Information Retrieval"*.

Advisors: C. Meinel and T. Engel.
Cotutelle Hasso Plattner Institute

Michael Stieghahn *"Law-Aware Access Control for International Financial Environments"*.

Advisor: T. Engel.
Industrial PhD with Commerzbank

Daniel Fischer *"Routing and Security Challenges in Next Generation Satellite Networks"*.

Advisor: T. Engel.
Industrial PhD with ESA

Events

Distinguished Lecture by Prof. H.J. Siegel (Colorado State University, USA, and CSU Information Science and Technology Center ISTeC): Reliability with Uncertainties: Stochastic Model of Robust Resource Management for Computing Systems. January, 2010

3rd Workshop on Security and Trust, January, 2010

Distinguished Lecture by Prof. Johannes A. Buchmann (Technical University of Darmstadt, Germany): Privacy and confidentiality in the future Internet. January, 2010

Distinguished Lecture by Prof. Bart Jacobs (Technical University Eindhoven, The Netherlands): Smart cards in public transport: the Mifare Classic Case. February, 2010

Distinguished Lecture by Prof. Rafael Capurro (University of Wisconsin-Milwaukee, USA): Information Ethics. May, 2010

Distinguished Lecture by Prof. Ronald L. Rivest (MIT, USA): Security of Voting Systems. May, 2010

1st Luxembourg-Polish Workshop on Security and Trust, May 2010

First European Summit on the Future Internet, June 2010

Kahn-Fest: The New Codebreakers – A Celebration of the 80th Birthday of David Kahn, June 2010

Distinguished Lecture by Prof. Jean-Raymond Abrial (ETH Zurich, Switzerland): Faultless Systems: Yes we Can. July, 2010

Distinguished Lecture by Prof. Aad Van Moorsel (Newcastle University, UK): The Role of Science in Cybercrime Prevention and Computer Security. July, 2010

Distinguished Lecture by Jan Camenisch (IBM, Zuerich), **Stefan Brands** (McGill Univ, Montreal) and **Dalia Daoud Suleiman KHADER** (SnT, Luxembourg): Minimal Data Disclosure, October 2010

Distinguished Lecture by Prof. Jürg Kohlas (University of Fribourg): The Computational Way to Argue. November, 2010

Summer School 2010: Verification technology, systems & applications, September 2010

... and more than 50 other research seminars.

Luxembourg, worldwide leader of the new Internet based on IPv6

First European Summit on the Future Internet

Schneller und sicherer durchs Netz

Made in heaven: SES and Uni.lu

SnT specialization in Entrepreneurship program

Vers la democratization d'Internet **IT One Award**

L'Université du Luxembourg s'implique dans la recherche spatiale

Unsere Visionen werden Projekte

SES and University sign long term partnership agreement

Standort als Zentrum der Satellitenforschung etablieren

Minimal Data Disclosure

Internet bleibt Wirtschaftsmotor, Comeback mit Potenzial

2,1 millions d'euros pour la recherche

Codebreakers

Er verhalf der Kryptologie zum Durchbruch: Kryptologen feierten 80. Geburtstag von David Kahn

Un partenariat déjà en orbite

JNI's Interdisciplinary Centre for Security, Reliability and Trust
SnT presents ICT Innovation for secure, reliable and trustworthy
ICT systems /services

Accord de partenariat entre la SES
et l'Université du Luxembourg

The SnT is continuously producing news and headlines like the above mentioned. Scientists from SnT are regularly meeting journalists to provide latest information on recent research projects. In 2010 press conferences, e.g. with Minister Biltgen on the 1st European Summit on the Future Internet, or visits of TV journalists from RTL, led to more than 60 reports in about 25 different newspapers, radio stations, web portals and TV programs.

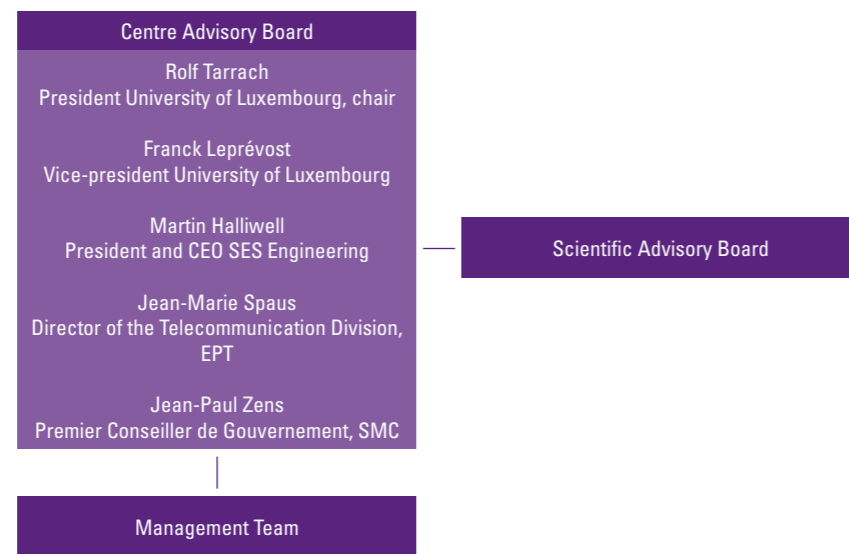
Organization

Governance of SnT

A Centre Advisory Board, chaired by the President of the University of Luxembourg advises the President on the Centre's activities (strategy, yearly plan,

budget, monitoring, review, etc.). A Scientific Advisory Board reviews the activities of the Centre and provides input and recommendations on future activities.

The Director is appointed by the university's board of governors and is responsible for the day-to-day management.

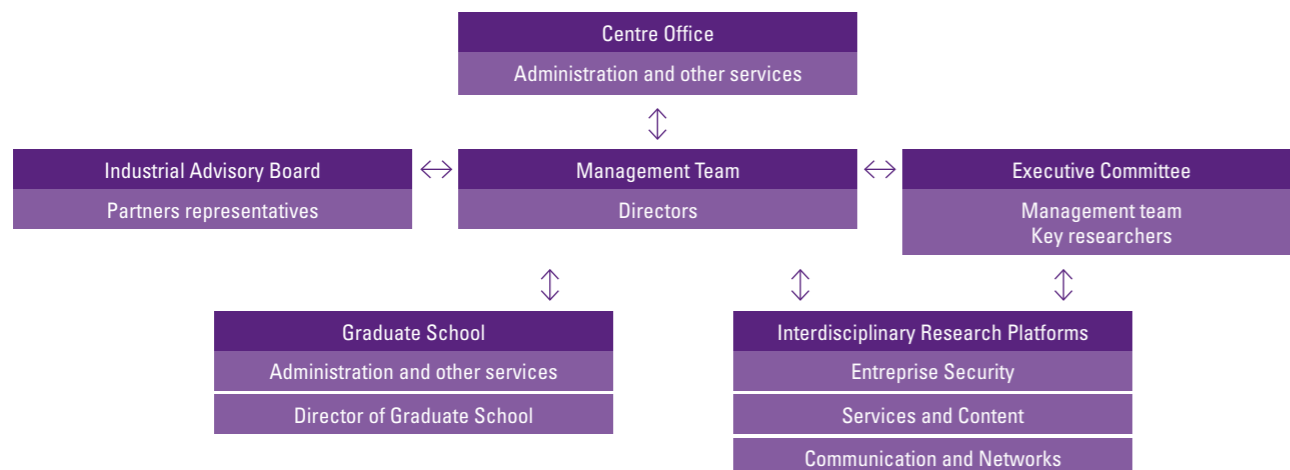


Organisation of SnT

The Industrial Advisory Board (IAB) brings together representatives from Centre partners. The IAB advises the Centre management on strategic issues and provides a platform for launching joint

research projects. Research activities are primarily carried out in three application areas covering Security, Reliability and Trust in:

1. Enterprise Security
2. Services and Content including e-Government
3. Communication and Network Infrastructures



People

Faculty

- › Prof. Dr. Björn OTTERSTEN, Director
- › Prof. Dr. Thomas ENGEL, Vice-director
- › Prof. Dr. Alex BIRYUKOV
- › Prof. Dr. Pascal BOUVRY
- › Prof. Dr. Mark COLE
- › Prof. Dr. Pierre KELSEN
- › Prof. Dr. Yves LE TRAON
- › Prof. Dr. Romain MARTIN
- › Prof. Dr. Sjouke MAUW
- › Prof. Dr. Peter RYAN
- › Prof. Dr. Jürgen SACHAU
- › Prof. Dr. Leon VAN DER TORRE

Researchers

- › Dr. Daniel ARAPOGLOU
- › Dr. Djamila AOUADA
- › Dr. Martin CAMINADA
- › Dr. Symeon CHATZINOTAS
- › Dr. Jianguo DING
- › Dr. Bernabé DORRONSORO
- › Dr. Jérôme FRANCOIS
- › Dr. Raphael FRANK
- › Dr. Martin HLAVÁČ
- › Dr. Dalia KHADER
- › Dr. Jacques KLEIN
- › Dr. Vincent KOENIG
- › Dr. Barbara KORDY
- › Dr. Simon KRAMER
- › Latif LADID
- › Dr. Gabriele LENZINI
- › Dr. Qin MA
- › Dr. Roderick MC CALL
- › Aurel MACHALEK
- › Dr. Foued MELAKESSOU
- › Dr. Tejeddine MOUELHI
- › Dr. Andriy PANCHENKO
- › Dr. Yoann PIGNÉ
- › Dr. Marc POULY
- › Dr. Sasa RADOMIROVIC
- › Dr. Marcin SEREDYNSKI
- › Dr. Péter SCHAFFER
- › Dr. Bhavani SHANKAR
- › Dr. Julien SCHLEICH
- › Dr. Radu STATE
- › Dr. Wei WANG
- › Dr. Andreas ZINNEN
- › Dr. Gan ZHENG

Research Fellows

- › Dr. Jacques BUS
- › Dr. João SCHWARZ DA SILVA
- › Prof. Dr. Christoph MEINEL

Visiting Researchers

- › Dr. Richard CLAYTON, University of Cambridge
- › Prof. Dr. Guido BELLA, University of Torino

Staff

- › Stéphanie ANNET, communications and events assistant
- › Laurent BETRY, financial controller
- › Isabelle CHESNAY, project coordinator
- › Marie-France GALLO, Human Resources assistant
- › Dirk HANS, head of communications
- › Magali MARTIN, administrative assistant
- › Nathanaëlle MINARD, project coordinator
- › Dr. Jean SCHWEITZER, project development manager
- › Stefanie ÖSTLUND, project coordinator

PhD Candidates

- › Alexandre BARTEL
- › Benoît BERTHOLON
- › Sheila BECKER
- › Christoph BRANDT
- › Xihui CHEN
- › Dimitrios CHRISTOPOULOS
- › Silvano COLOMBO TOSATTO
- › Dr. Daniel FISCHER
- › Cesar DIAS
- › David FOTUE
- › Frederic GARCIA
- › Stefan HOMMES
- › Markus JOSTOCK
- › Yves NEISIUS
- › Dr. Michael NOLL
- › Frederic PINEL
- › Thorsten RIES
- › Arnab ROY
- › Sandra SCHMITZ
- › Patrick SCHWEITZER
- › Apostolos STATHAKIS
- › Dr. Michael STIEGHAHN

- › Eleftherios SKOUTARIS
- › Cynthia WAGNER
- › Gérard WAGENER
- › Shaonan WANG

MS Students

- › Walter BRONZI
- › Remus-Alexandru DOBRICAN
- › Mateusz GUZEK
- › Diana MAROSIN

Projects

FNR CORE projects

Project name	Principal investigator	Researcher(s)	Partner
ATREES – Attack Trees	Prof. Sjouke Mauw	Dr. B. Kordy Dr. S. Radomirovic	
CO2SAT – Cooperative and Cognitive Architectures for Satellite Networks	Prof. Björn Ottersten	Dr. S. Chatzinotas Dr. G. Zheng Dr. D. Pantelis Arapoglou Mr. D. Christopoulos	SES
GreenIT – Energy-efficient Resource Allocation in Autonomic Cloud Computing	Prof. Pascal Bouvry	Dr. Dorronsoro	
LAAMI – Logical Approaches for Analyzing Market Irrationality	Prof. Björn Ottersten	Dr. M. Caminada	LSF
MARCO – Managing Regulatory Compliance: a Business-Centered Approach	Prof. Pierre Kelsen	Prof. Leon Van der Torre Dr. Q. Ma	
MITER – Modeling, Composing and Testing of Security Concerns	Dr. Jacques Klein		
MOVE – Mobility Optimization using Vehicular network technologies	Prof. Thomas Engel	Dr. R. Frank Dr. A. Panchenko Dr. J. François	UCLA
SeRTVS – Secure Reliable and Trustworthy Voting System	Prof. Peter Ryan	Dr. D. Khader Dr. G. Lenzi	

EU FP7 projects

Project name	Principal investigator	Researcher(s)
ceFIMS – Coordination of the European Future Internet forum of Member States	Prof. Thomas Engel	L. Ladid
EFIPSANS – Exposing the Features in IP version Six Protocols that can be exploited/extended for the purposes of designing/building Autonomic Networks and Services	Prof. Thomas Engel	Dr. J. François L. Ladid Dr. P. Schaffer
SECRICOM – Seamless Communication for Crisis Management	Prof. Thomas Engel	A. Machalek

ESA projects

Project name	Principal investigator	Researcher(s)	Partners
Location Assurance Service Provider (LASP)	Prof. Sjouke Mauw	X. Chen Dr. G. Lenzi Dr. J. Pang	itrust
MIMO – MIMO Hardware Demonstrator	Prof. Björn Ottersten	Dr. B. Shankar	SES
SMO-MLS – Securing Mission Operations using Multi-Level Security	Prof. Thomas Engel	E. Skoutaris	
Techniques and Technologies for multi-spot beam Ku-band Satellite Networks	Prof. Björn Ottersten	Dr. B. Shankar	EADS-Astrium

FNR AFR PhD candidates

Project name	Principal investigator	Researcher(s)
3SOLAW – Three strikes, you're out! A legal analysis of the latest legislative measures to fight illegal activities on the world wide web	Prof. Mark Cole	S. Schmitz
Confidentiality and Integrity over Cloud Computing Platforms	Prof. Pascal Bouvry	B. Bertholon
Development of norm representation languages to represent and reason about business process regulations	Prof. Leon Van der Torre	S. Colombo Tosatto
DYNOST – Dynamic and Composite Service-Oriented Architecture Security Testing	Prof. Yves Le Traon	A. Bartel
Investigation of boundary conditions for a reliable and efficient control of energy systems formed by highly parallelized off-grid Inverters.	Prof. Juergen Sachau	M. Jostock
ProCRob – Programming Cognitive Robotics	Prof. Leon Van der Torre	P. Ziafari
Security Analysis through Attack/Defense Trees	Prof. Sjouke Mauw	P. Schweitzer

Partnered projects

Project name	Principal investigator	Researcher(s)	Partner
2D/3D Sensor Fusion	Prof. Björn Ottersten	F. Garcia	IEE S.A AFR/FNR
End-to-end Web Service Security	Prof. Thomas Engel	S. Wang	P&T Luxembourg
Energy Optimization and Monitoring in Wireless Mesh Sensor Networks	Prof. Thomas Engel	D. Fotue	Ville de Luxembourg
Feasibility Study for Topology Optimization	Prof. Thomas Engel	Dr. F. Melakessou Dr. J. François	Ministry of Economy and Foreign Trade
Lewis – Luxembourg Early-Warning analysis and Information sharing System	Prof. Peter Ryan		Ministry of Economy and Foreign Trade
Lewis II – Collection of Passive DNS and Network Telescope Data	Prof. Peter Ryan	Dr. M. Hlavàc	Ministry of Economy and Foreign Trade
Multimedia Sensor Networks	Prof. Thomas Engel	S. Hommes	P&T Luxembourg AFR/FNR
Potential business for an advanced spread spectrum measurement system for satellite testing	Dr. Symeon Chatzinotas		MESR SES
Research Program in Multi Sensor Fusion	Prof. Björn Ottersten	Dr. D. Aouada	IEE S.A.
Research Program in Satellite Systems	SnT Program	Dr. D. Arapoglou Dr. G. Zheng Dr. S. Chatzinotas	SES
Research Program in Vehicular Networks and Smart Homes	SnT Program	Dr. R. Frank	P&T Luxembourg
SaPRO – Satellite Payload Reconfiguration Optimization	Prof. Pascal Bouvry	Dr. G. Danoy A. Stathakis	SES
Secure and private location proofs/ Architecture and design for location based services	Prof. Sjouke Mauw	X. Chen	itrust Consulting AFR/FNR
Self-organizing Security Sensors in Highly-Distributed IP Networks	Prof. Thomas Engel	G. Wagner	SES AFR/FNR
Trusted Location Based Services	Prof. Thomas Engel	Y. Neisius	Telindus AFR/FNR

FNR AFR post-docs

Project name	Principal investigator	Researcher(s)
A computational framework for Apprehending Evolving Malware and Malware Engineers	Prof. Peter Ryan	Dr. S. Kramer
Autonomic Security management in dynamic networks	Prof. Pascal Bouvry	Dr. J. Ding
MUTERSYS – Formal Mutation, test for Resilient System and their Security properties	Prof. Yves Le Traon	Dr. Y. Elrakaiby
INTERCOM – Energy-efficient Networking in Autonomic Cloud computing	Prof. Pascal Bouvry	Dr. D. Kiazovich
V2V – Efficient data transfer in vehicle2vehicle wireless communication networks	Prof Pascal Bouvry	Dr. Y. Pigné

Other projects

Project name	Principal investigator	Researcher(s)	Funding scheme
Cognitive Radio and Networking for Cooperative Coexistence of Heterogeneous Wireless Networks	Prof. Björn Ottersten	Dr. S. Chatzinotas	COST Action IC0902
Cooperative Radio Communications for Green Smart Environments	Prof. Björn Ottersten	Dr. S. Chatzinotas	COST Action IC 1004
DYNOSOAR	Prof. Yves Le Traon	Dr. T. Mouelhi	UL internal
ETN-TRICE European Thematic Network for Teaching, Research and Innovations in Computing Eduaction	Prof. Thomas Engel	L. Ladid S. Östlund	FP7 LLP
ISI – The Integral Satcom Initiative	Prof. Björn Ottersten		ESA
Propagation Tools and Data for Integrated Telecommunication, Navigation and Earth	Prof. Björn Ottersten	Dr. P-D. Arapoglou	COST Action IC0802
SatNEx III – The work of the Satellite Communication Network of Excellence III	Prof. Björn Ottersten	Dr. P-D. Arapoglou	ESA
WiSafeCar – Wireless traffic Safety Network between Cars	Prof. Pascal Bouvry	Dr. Y. Pigné	CELTIC Program

Publications

Journal publications:

1. Amalio, Nuno; Kelsen, Pierre; Ma, Qin; Glodt, Christian: *Using VCL as an Aspect-Oriented Approach to Requirements Modelling*, Transactions on Aspect Oriented Software Development, vol. 7, 2010, pp. 151 – 199
2. Aouada, Djamilia; Krim, Hamid: *Squigraphs for Fine and Compact Modeling of 3-D shapes*, IEEE Transactions on Image Processing, 19 (2010), no. 2, pp.306–321, vol. 19, 2010, pp. 306 – 321, ISSN: 1941-0042
3. Benoit, Baudry; Sudipto, Ghosh; Franck, Fleurey; Robert, France; Yves, Le Traon; Jean-Marie, Mottu: *Barriers to Systematic Model Transformation Testing*, Communications of the ACM, vol. 53, no. 6, ACM, 2010, pp. 139 – 143, ISSN: 0001-0782
4. Björnson, Emil; Ottersten, Björn: *A Framework for Training-Based Estimation in Arbitrarily Correlated Rician MIMO Channels with Rician Disturbance*, IEEE Transactions on Signal Processing, vol. 58, no. 3, IEEE, 2010, pp. 1807 – 1820, ISSN: 1053-587X
5. Buttyán, Levente; Schaffer, Peter: *PANEL: Position-based Aggregator Node Election in Wireless Sensor Networks*, International Journal of Distributed Sensor Networks, vol. 2010, Hindawi Publishing Corporation, 2010, pp. 1 – 9
6. Eduardo, Almeida; Gerson, Sunyé; Yves, Le Traon; Patrick, Valduriez: *Testing peer-to-peer systems, Empirical Software Engineering*, vol. 15, no. 4, Springer, Netherlands, 2010, pp. 346 – 379, ISSN: 1382-3256
7. Emil, Björnson; Randa, Zakhour; David, Gesbert; Björn, Ottersten: *Cooperative Multicell Precoding: Rate Region Characterization and Distributed Strategies with Instantaneous and Statistical CSI*, IEEE Transactions on Signal Processing, vol. 58, no. 8, 2010, pp. 4298 – 4310
8. François, Jérôme; Abdelnur, Humberto; State, Radu; Festor, Olivier: *Machine Learning Techniques for Passive Network Inventory*, Transactions on Network and Service Management, vol. 7, no. 4, IEEE, 2010, pp. 244 – 257
9. Gershman, Alex B.; Sidiropoulos, Nicholas D.; Shahbazpanahi, Shahram; Bengtsson, Mats; Ottersten, Björn: *Convex Optimization-based Beamforming: From Receive to Transmit and Network Designs*, IEEE Signal Processing Magazine, vol. 27, no. 3, IEEE, 2010, pp. 62 – 75
10. Huang, Yongming; Yang, Luxi; Bengtsson, Mats; Ottersten, Björn: *A Limited Feedback Joint Precoding for Amplify-and-Forward Relaying*, IEEE Transactions on Signal Processing, vol. 58, no. 3, IEEE, 2010, pp. 1347 – 1357

11. Jean-Marie, Mottu; Benoit, Baudry; Yves, Le Traon: *Construction de tests qualifiés de transformation de modèles*, Technique et Sciences Informatiques, Numéro Spécial L'ingénierie dirigée par les modèles, vol. tba, Hermes, 2010, pp. 1 – 1
12. Joel, Grotz; Ottersten, Björn; Jens, Krause: *Signal detection and synchronization for interference overloaded satellite broadcast reception*, IEEE Transaction on Wireless Communications, 2010, pp. 1 – 1
13. Joerg, Kienzle; Wisam, Al Abed; Jacques, Klein: *Aspect-Oriented Design with Reusable Aspect Models*, In Transactions on Aspect-Oriented Software Development (TAOSD), LNCS 6210, Springer 2010, p. 272 – 320, 2010, pp. 1 – 1
14. Ding, Jianguo: *Advances in Network Management*, USA, CRC press, Taylor & Francis Group, 2010, ISBN: 978-1420064520
15. Krysiak, Frank; Schweitzer, Patrick: *The optimal size of a permit market*, Journal of Environmental Economics and Management, 60 (2010), no. 2, pp. 133 – 143, 2010, pp. 1 – 1
16. Simon, Järmyr; Ottersten, Björn; Eduard, Jorswieck: *Statistical Precoding with Decision Feedback Equalization over a Correlated MIMO Channel*, IEEE Transactions on Signal Processing, vol. 58, no. 12, 2010, pp. 6298 – 6311, ISSN: 1053-587X
17. Suchanecki, Zdzislaw; Gomez-Cubillo, Fernando: *Evolution semigroups and time operators on Banach spaces*, Journal of Mathematical Analysis and Applications, vol. 371, no. 2, ELSEVIER, 2010, pp. 454 – 464, ISSN: 0022-247X
18. Schmitz, Sandra; Siry, Lawrence: *Online-Archive – "Der ewige Pranger im Internet?"*, Digitale Evolution – Herausforderungen für das Informations- und Medienrecht, OIWR Verlag für Wirtschaft, Informatik und Recht, 2010, 2010, pp. 217 – 232, ISBN: 978-3939704508
19. Schweitzer, Pascal; Schweitzer, Patrick: *Connecting face hitting sets in planar graphs*, Information Processing Letters, vol. 111, no. 1, Elsevier, 2010, pp. 11 – 15, ISSN: 0020-0190
20. Wu, Yining; Caminada, Martin; Podlaszewski, Mikolaj: *A Labelling-Based Justification Status of Arguments*, Proceedings of the 13th International Workshop on Non-Monotonic Reasoning (NMR) (2010), vol. Studies in Logic, 3 (2010), no. 4, 2010, pp. 12 – 29
21. Yongming, Huang, Zheng, Gan; Mats, Bengtsson; Kits, Wong; Björn, Ottersten: *Distributed Multi-cell Beamforming Design with Limited Inter-cell Coordination*, IEEE Transactions on Signal Processing, 2010, pp. 1 – 1

Conference proceedings:

22. Abdelkefi, Atef; Jiang, Yuming; Wang, Wei; Aslebo, Arne; Kvittem, Olav: *Robust Traffic Anomaly Detection with Principal Component Pursuit*, ACM CoNEXT Student Workshop, ACM, 2010, ISBN: 978-1-4503-0468-9
23. Amalio, Nuno; Kelsen, Pierre; Ma, Qin: *Specifying structural properties and their constraints formally, visually and modularly using VCL*, EMMSAD 2010, vol. 50, Springer, 2010, pp. 50 – 261
24. Aouada, Djamilia; Baryshnikov, Yuliy; Krim, Hamid: *Mahalanobis-based Adaptive Dimension Reduction*, 20th International Conference on Pattern Recognition, IEEE Xplore, 2010, pp. 1 – 4
25. Björnson, Emil; Bengtsson, Mats; Ottersten, Björn: *Optimality Properties and Low-Complexity Solutions to Coordinated Multicell Transmission*, Proceedings IEEE Global Communications Conference (GLOBECOM), 2010, pp. 1 – 1
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