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Contents

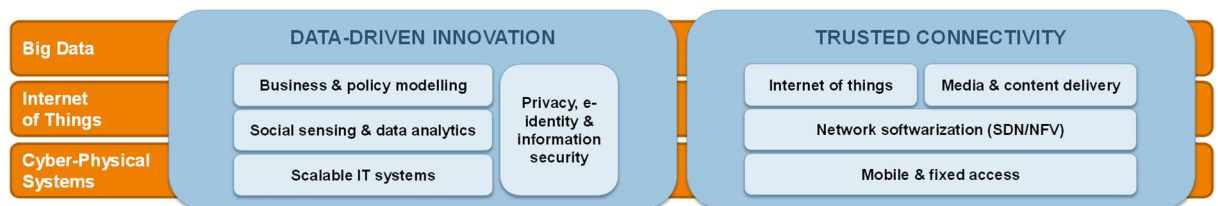
1	VP ICT	3
1.1	Summary	3
1.2	Short description	4
1.3	Highlights	4
1.4	Dynamics	9
2	Signature	10

1 VP ICT

1.1 Summary

Networked Information is the backbone of our economy, and one of the main drivers of transitions that are taking place in mobility, energy, health, and manufacturing (Smart Industry). Technological developments such as big data, the Internet of Things and cyber-physical systems give rise to an unprecedented volume of data and interconnected devices, increasingly linking the virtual and the physical world. ICT is thus both an *area of innovation* as well as a *key enabler for innovation*.

The VP ICT focuses its activities in two areas. *Data driven innovation* concerns the development of data services and platforms, including research into business models, privacy, and information security. Main objectives in this area are to remain leading in the European and national data ecosystems, to set up data ecosystems that develop data innovations for specific application areas, and to develop information security and privacy tooling. *Trusted Connectivity* aims to sustain these developments, for which high quality, secure and reliable access networks are essential. Its main objectives are to remain leading in digital infrastructure, media orchestration and to be a frontrunner in 5G development by setting up 5G Fieldlabs. Both areas encompass four focal areas.



Highlights in the field of *data driven innovation* in 2016 include setting up large scale data ecosystems such as in the Smart Dairy Farming, STOOP and Digital Factory projects. These projects use large amounts of data to optimize operations in dairy farming, gas networks and production environments respectively. Several projects have developed privacy preserving and information security frameworks, architectures and technologies that allow people to retain control over their data and attributes, such as TrustTester PRANAdata and RESPECT4U. Increasingly, these projects focus on the Healthcare domain. A third set of projects is concerned with coordination innovation efforts in specific domains or regions. Examples include the I4MS project on digital innovation hubs across Europe and TNO's efforts in the Metropoolregio Amsterdam/Almere.

The *trusted connectivity* research line focused on innovations in access networks and the next generation of mobile communications: the 5G next generation standard for mobile communication and network softwarization. 5G is expected to spur innovation in many different domains. Therefore, TNO is involved in setting up 5G Fieldlabs, for example in 5Groningen for precision farming and in the field of autonomous driving. Furthermore, in the area of network softwarization the Hi5 platform was successfully developed and KPN's 4G network was extended to this software-core network operator. In the field of media content delivery TNO applied its tiled streaming technology to virtual reality, which will lead to the startup Tiled Media. Innovations in this field were successfully tested during live events in the

Amsterdam Arena. A new development is the exploration of the use of blockchain technology, e.g. in the financial sector and for Smart Industry.

1.2 Short description

The VP ICT focuses its activities in two areas: data driven innovation and trusted connectivity.

Data driven innovation concerns the development of data services and platforms, including research into policy, business models, privacy and information security.

Objectives include:

- Establishing a leading position in big data, within Europe (via the Big Data Value Association) and nationally (via COMMIT2DATA and Almere's Big Data Value Centre).
- Shaping data ecosystems in specific application domains by setting up Fieldlabs, such as in the field of Smart Industry (e.g. Smart Dairy Farming, STOOOP, Digital Factory).
- Developing information security and privacy tooling, such as the TrustTester data validation technology, the PRANAdata privacy respecting architecture, and the RESPECT4U methodology for protection of personal data.

Trusted Connectivity aims to sustain these developments, for which high quality, secure and reliable access networks are essential. Its main objectives are:

- Expanding TNO's leading international position in the field of media and content delivery and virtual reality, also by testing innovations in the Amsterdam Arena Fieldlab.
- Consolidating our international position in the field of ICT standardization and specifically the emerging 5G standard, setting up (pre)5G Fieldlabs for 5G Proof of Concepts.
- Developing a leading position in blockchain technology nationally, by setting up a program in collaboration with financials and academic partners, focusing on setting up experimental Fieldlabs and on the implications of introducing distributed ledger technology.

Furthermore, important objectives of the VP ICT are stakeholder management to maintain connections with national (e.g. COMMIT2DATA, PI.lab, BDVC) and international (e.g. BVDA, AIOTI, 5GPPP, NEM) ecosystems and participate in standardization groups (e.g. ETSI, HbbTV). These activities aim to strengthen the propositions of the VP ICT.

1.3 Highlights

Research projects that were carried out are a mix of three types of projects: TNO knowledge investment projects, mixed funding European and national projects, and Topsector HTSM TKI projects. Most projects are mixed funding European and national projects. Few exclusively TNO funded projects are carried out, since knowledge projects are almost always carried out in cooperation with leading industry partners. This allows focus on the applicability of the research, by getting feedback from industrial partners and incorporating this feedback directly into the research.

Data driven innovation

Data driven innovation is concerned with the development of data services, platforms, and ecosystems, which are of increasing economic importance. Innovations in this domain encompass four focal areas: architectures for processing large quantities of data (*scalable IT systems*), data collection via sensors and development of algorithms for data processing (*social sensing and data analytics*), the development of privacy preserving architectures (*privacy, e-identity and information security*), and the development of business models and policies (*business and policy modelling*).



The development of *scalable IT systems*, large interconnected (sensor) systems, often takes place in specific application domains via setting up Fieldlabs, such as in the field of Smart Industry, or by using a regional collaborative approach, such as in the Metropoolregio Amsterdam/Almere, allowing for multiple aspects of the ICT transformation to take place in the same physical area. A notable example is the TKI project Smart Dairy Farming (see figure) that is developed in collaboration with several knowledge institutes, and

the companies Agrifirm, CRV, and FrieslandCampina. This project collects data from individual cows, processes these data centrally and subsequently provides the farmer with customized information on nutrition per cow. A second example of such a project is the TKI project STOOP, which develops a smart gas network. By measuring the state of gas pipelines using sensors and big data processing this project supports maintenance decisions.

The areas of *social sensing and data analytics* and *privacy, e-identity and information security* have largely merged. Central to this proposition is the development of information security and privacy respecting tooling, policies and technologies that allow the end user to retain control of his own data and attributes.



Examples are the TrustTester data validation technology, the PRANAdat privacy respecting architecture, and the RESPECT4U methodology for protection of personal data. The TrustTester data validation technology was envisioned to be implemented within government, for example for validating data for mortgage requests. While the TrustTester methodology was successfully developed, unfortunately the pilots that would be carried out with government and business partners fizzled. The PRANAdat privacy respecting architecture will continue

being developed and application will focus on the Healthcare domain. The RESPECT4U methodology can be used within organizations that aim for responsible data handling (see figure).

In the field of information security, research activities are joined up in the Shared Research Program Cybersecurity on targeted attack and anomaly detection and on autonomous response to attacks. The SRP is set up in collaboration with financial partners such as banks and insurance companies. Furthermore, three projects are co-sponsored within the NWO program, which allow TNO to gain insight into fundamental research in the field of deep packet inspection and visualization, anomaly detection, and privacy patterns, via supervision of PhD's.

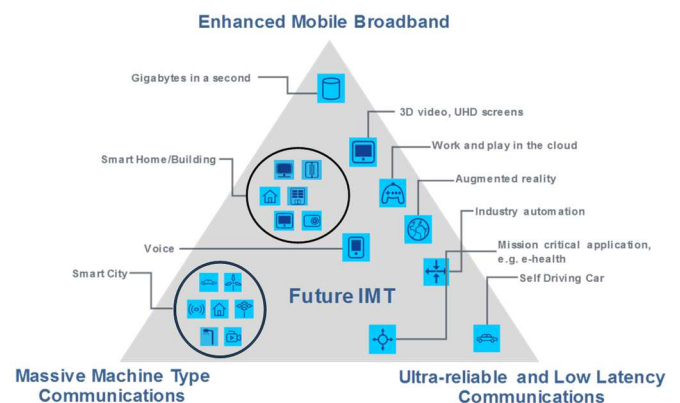
Business and policy modelling is concerned with the development of the innovation and valorization strategies and business models for data ecosystems. Activities in this domain include coordination actions across Europe spurring digital innovation. For example, the MAKE-IT project investigates the maker movement to share best practices and explore its impact on traditional industry. The I4MS project coordinates digital innovation hubs across Europe. Within the government sector, the TOOP project focuses on further developing and implementing the 'once only policy' guideline for information sharing between citizens and government. It aims to establish interoperability creating seamless service delivery between EU governments.

Trusted Connectivity

Central to this proposition is operating secure and reliable *mobile and fixed access* to networks, ensuring manageability of the increased complexity of these networks that need to work across operators (domains) and vendors (platforms). The focus is optimization of current, heterogeneous, networks (DSL, 4G, Wi-Fi) and being at the forefront of future networks (5G). *Network softwarization* can provide an extremely powerful concept to increase robustness, also increasing flexibility and thus improving the business case when demand is uncertain or highly irregular. The emergence of the *Internet of Things*, connecting almost every device imaginable to the internet, and the ever increasing consumption of video content (*media and content delivery*), which takes up around eighty percent of the existing bandwidth for telecommunications, rely on and shape the trusted connectivity proposition.

In the field of *fixed access*, TNO has long been a center of excellence on xDSL. To remain involved in world-wide developments, TNO participates in the CELTIC-Plus GOLD project that aims to develop cost-effective ultra-broadband access level based on the G.fast standard. G.fast has demonstrated an increase the throughput of copper cables to nearly 1Gbps, and the GOLD project aims to push G.fast even further to multiple-gigabit copper access rates for fifth generation fixed broadband.

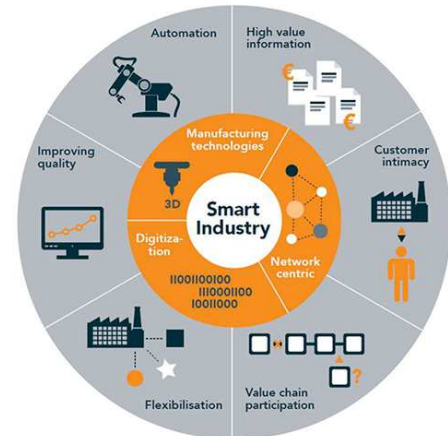
For *mobile access*, an important objective of the VP ICT is to shape the 5G landscape and 5G ecosystem in the Netherlands and Europe. 5G is the next generation standard for mobile communication. It will reconcile contrasting design parameters such as high bandwidth, ultralow latency and massive-machine type communication



(see figure¹). This standard is expected to encompass Internet of Things and M2M connectivity and thereby become a comprehensive framework for future connectivity.

TNO is leading in 5G standardization and participates in 5G Fieldlabs with industry stakeholders (e.g. KPN, other telco's, Huawei, Ericsson) developing Proof of Concepts and pilots in different sectors with innovations on mobile access, SDN/NFV and IoT.

- 5G Fieldlab Indoor: the Hi5 platform will be expanded to a multi-vendor network operator for research purposes.
- 5G Fieldlab Rural areas: the 5Groningen agricultural pilot develops fully automated agricultural machinery using a connected dense sensor network.
- 5G Fieldlab Automated Driving: piloting automated driving with 5G technology.
- 5G Fieldlab for live events/media in Amsterdam Arena.



Network softwarization is expected to become paramount in order to facilitate the ever increasing data throughput. Software Defined Networking (SDN) and Network Function Virtualization (NFV) are the main technologies. TNO developed a facility named Hi5 that allows for experimentation with these network technologies. Hi5 is a hybrid Virtual Network Function/Physical Network Function-testbed and development platform with the purpose of obtaining operator and business user expertise, and gaining experience with innovations (IPR and tools) and third party developments. A pilot project was carried out integrating and extending KPN's 4G Lab (a research live network based on the latest LTE innovations in commercial radio networks) to Hi5.

The *Internet of Things* research line is comparable to scalable IT systems, but with a focus on connecting devices. It aims to connect every imaginable device to the Internet and process its data in order to create new services. Highlights in this field include the mixed funding ITEA project Enhanced M2M grid that develops quality aware sensor data processing for electricity networks. Furthermore, the H2020 project Wi5 focuses on the interference of Wi-Fi signals in the Home environment. Furthermore, based on the work TNO has carried out on the SAREF ontology, TNO has been invited to contribute to Google's SCHEMA.org ontology for the Internet of Things.

TNO has established a leading international position in the field of *media and content delivery*, which will be continued in the MOS2S ITEA project that will develop and test audiovisual smart city technologies and solutions in the context of citizen needs and test them in a smart city environment. Furthermore, TNO's tiled streaming technology has been successfully adapted for use in virtual reality

¹ Source: Langtry, C., ITU Radiocommunication Bureau, 'Standards development for wireless broadband access', https://www.itu.int/net4/wsis/forum/2016/Content/AgendaFiles/document/9d6c7b67-33a7-4ac6-96c7-ebf2231d83c2/ITU-BR_Colin_Langtry.pdf.

devices, leading to the creation the Tiled Media startup. Furthermore, innovations in this field are tested during live events in the Amsterdam Arena.

Stakeholder management and standardization

Important objectives of the VP ICT are stakeholder management and ICT standardization. Both aim to strengthen TNO's knowledge position and leading role in the (research) field. A first aspect is to maintain a good connection with international R&D&I programs such as Horizon 2020 and EIT Digital. On the national level TNO played a leading role in setting up the COMMIT2DATA proposal, based on the KIA-ICT, and TNO will intensify cooperation with NWO. Within the COMMIT2DATA program, NWO calls have been set up aiming to develop generic big data capabilities as well as applications in different domains, such as Smart Industry, energy and mobility.



Furthermore, TNO is represented on board level, such as at the European Big Data Value Association (BDVA) and the 5GPPP. Furthermore, TNO participates in the European AIOTI and NEM platforms in the field of

Internet of Things and media orchestration respectively. At the local level TNO participates in the Big Data Value Center (with the Economic Boards of Almere, Amsterdam, Utrecht, eScience Center). Within the privacy, e-identity and information security research line TNO's board membership of the PI.lab collaboration with Radboud University and TILT (Tilburg University) is an important asset to strengthen ties with fundamental research. For these organizations, TNO organized several networking events, such as the Big Data Value Association Mini Summit in March, the Small Big Data Conference in September, and the PI.lab annual conference in December.



TNO has a leading role in international standardization groups and a substantial IP portfolio (with partner KPN), especially network standards. For example, TNO actively helps shaping the 5G standard through its association with the 5GPPP. The standardization efforts within the VP ICT include working on more than twenty standards, including mobile networks, media content delivery, M2M service development, and privacy.

Several parttime professors are associated with the VP ICT program, connecting to relevant Dutch universities (University of Groningen, University of Twente, University of Amsterdam, Leiden University, Delft University of Technology, Radboud University). Hans van den Berg's research on performance and quality of service in ICT in different domains connects TNO to the CTIT research group at the University of Twente. Rob Kooij (Delft University of Technology) investigates the robustness of networks and has a strong link with cybersecurity. Wessel Kraaij (Radboud University, Leiden University) is active in the data science field, especially in relation to applications in health. Jan van Erp's research into tangible user interaction at the University of Twente looks at value creation based on (big) sensor data on the personal level and the tactile internet. David Langley, as associate professor at the University of Groningen in the field of internet, innovation, and strategy investigates emerging business models, for example, for the Internet of Things.

1.4 Dynamics

Three main research initiatives were set up within the VP ICT in 2016: several programs around blockchain technology, an investigation into beamforming for 5G and a call for seed projects aiming to identify innovative topics for the Roadmap in the new strategy period that starts in 2018.

Within the Topteam ICT TNO is involved in setting up the national Blockchain Competence Centre (BC4). Simultaneously, the VP ICT has supported the development of a research agenda for TNO in this area, which will allow us to contribute to BC4. This research agenda combines the development of technical competencies such as security, and developing strategic capabilities related to the wider societal impact of distributed ledger technologies, for instance on government and on social innovation. Based on this research agenda we also help shaping national ecosystems, such as the Techruption initiative in Heerlen, and Fieldlabs that allow for experimentation and development of blockchain applications, for example in the field of Smart Industry.

Together with TNO's Radar research group the VP ICT is investigating the opportunity to develop IP in the field of antennae (beamforming) for 5G, aimed at telecom vendors. Simultaneously, we investigate whether we can also develop a position in front end design (antennae and chipset). The objective is to determine whether this could become a viable proposition for TNO in 2017.

The third initiative was a call for seed projects: small exploratory projects that may, in time, grow into new Roadmap topics. Criteria for funding were technologically innovative as well as having commercial opportunities. The call yielded nearly thirty proposals; six projects were selected.

- *Addressable TV*: exploration of targeted (personalized) advertising for television.
- *Confidentiality-preserving collaborative intrusion detection systems*: application of secure multi-party computation protocols to the domain of network intrusion detection.
- *Network-integrated media delivery*: development of a Proof of Concept of cross-layer NIMD in the home environment.
- *On the fly changes of data models*: switching between (big) data sources needed for data analysis without interrupting the analysis.
- *Data locality*: exploration of state of the art of decentralized data processing.
- *Smart adaptive systems*: exploration of state of the art of adaptive IoT.

Some activities in the field of Cybersecurity (standardization efforts, the COST action RECODIS and the support for the full professorship of Rob Kooij) are not continued within the VP ICT in 2017 as they become part of TNO's Cybersecurity Roadmap.

2 Signature

Eindhoven, February 28th 2017

TNO



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