Innovation enabled by Information and Communication Technologies

A Swedish Innovation and Research top level agenda for the area of Information and Communication Technologies

April 12, 2013

Content

1 Executive summary

Strong attractiveness and competitiveness, sustainable growth and sustainable societal development are some of the main goals for Sweden. Information and Communication Technology, ICT, is a strategic innovation area that enables those overall objectives.

Our vision is that Sweden will be the innovation center for development of competitive, usable and sustainable products and services enabled by ICT. Innovation enablers by ICT program addresses the whole ICT area; from electronics and embedded systems in industrial products, administration systems and vehicles to telecom systems, media distribution, gaming and everything in between. Beyond the year 2020, we envision that Sweden is the world's most sustainable society where the entire population, companies, schools and government, all have access to the world's most advanced ICT infrastructure which has dramatically reduced its energy consumption compared to today, and enabling Swedish companies to be market leading. All of Sweden is covered by mobile broadband, and more than 1000 million "things", including, meters, sensors and vehicles are connected to the Internet. The traditional strong Swedish cooperation between industry, academia and authorities will be boosted by innovative new agile methodology to execute research and innovation.

ICT is a well-established business by itself and is a very important enabler in non-ICT business. The survey "Företag inom informations- och kommunikationsteknik i Sverige" [1] shows that at least 160 000 people work in business with ICT as their main area. Estimations are that at least 100 000 additional people work with ICT in other business that do not have ICT as their main area. The growth of employees has been an impressive 13% during the last five years period despite the fact that there has been a downturn in economy during the same period. The ICT business is of major economic importance by itself, and has very large impact on the overall Swedish economy and trade with products and services.

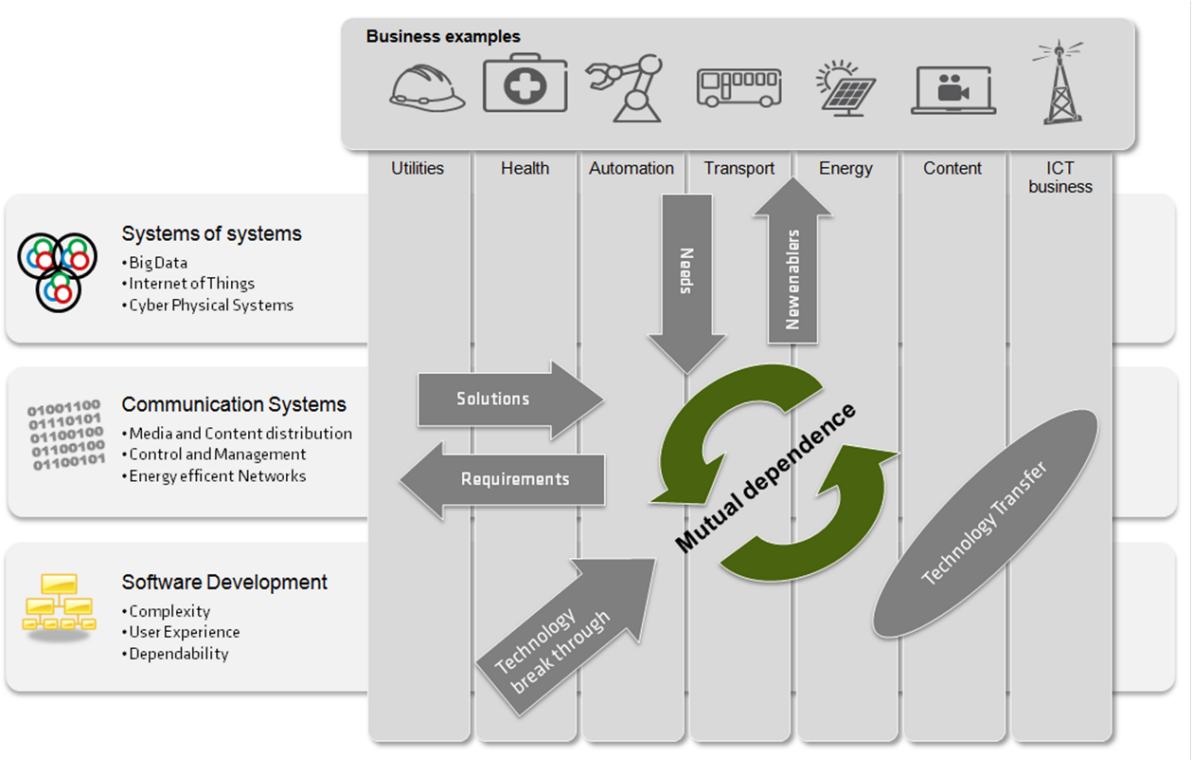

Figure 1: ICT as an Innovation enabler for all kinds of Swedish business

Through a strategic innovation area “Innovation Enablers by ICT” we will act as an enabling catalyst for all kinds of Swedish business; SME, public sector and industry. Projects and networking activities will be launched in the three upcoming areas of strength for ICT in Sweden; Systems of systems, Communication systems and Software development. By focusing on innovation enablers by those areas of strength, Swedish organizations in ICT business and non-ICT business will take lead in the market to provide new products and services.

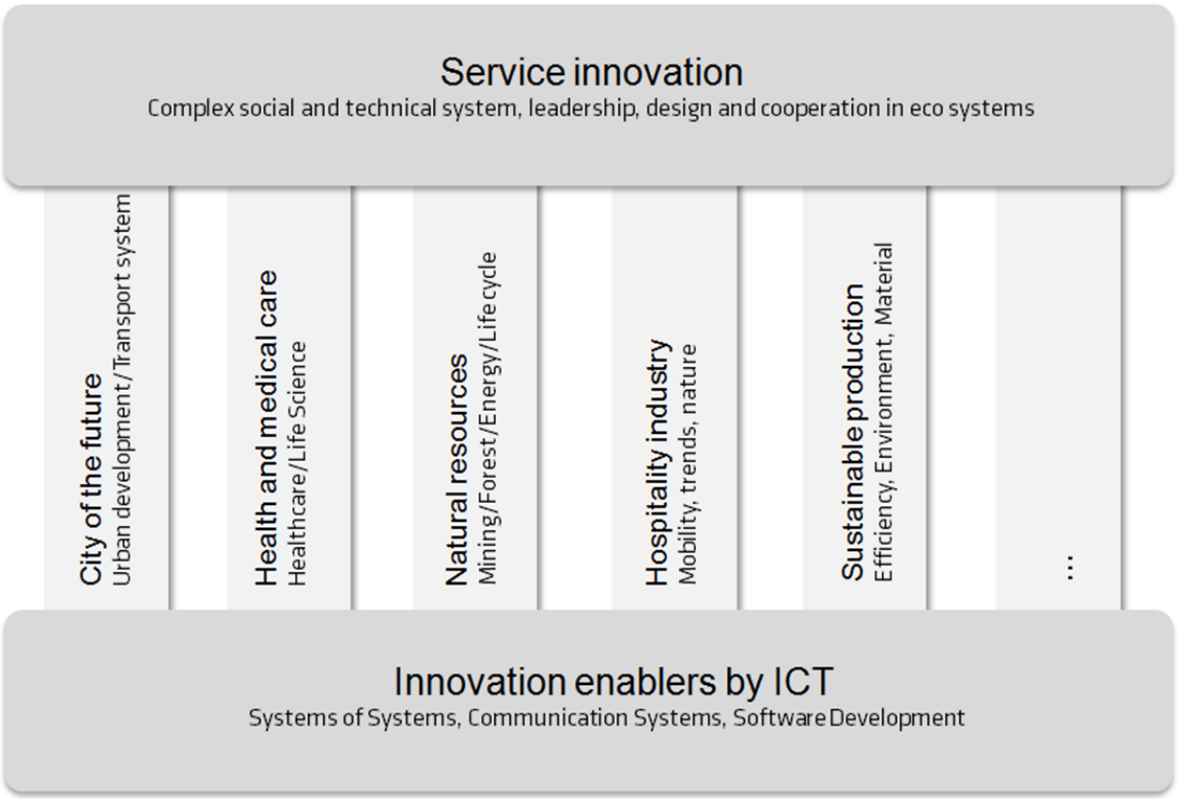

Figure 2: Strength to Swedish market with Innovation enablers by ICT, Service innovation agenda [4]

With Innovation enablers by ICT, Swedish business will with short time to market provide new sustainable products and services innovations for the world market and strengthen sustainable growth in Sweden.

2 Background

The Swedish industry will in general be shifting its focus from mechanics and electronics hardware to software as a differentiator and provider of customer value. Today, competitive vehicle and automation industries require dramatic rationalization of their production to offer advanced ICT enabled solutions solving the current customers' needs. Clearly, ICT competence and ICT infrastructure are key competitive advantages now and in the future.

ICT has contributed to all people's quality of lives. For instance, the use of electronic mail was introduced on a general scale around 1990 but on incompatible systems. The World Wide Web was introduced in early 1992 and reached commercial use in the late 90's. Internet banking and booking of tickets were commonly used in the beginning of year 2000.

Searching for best offer on products and services were well in usage in 2005 and people started watching TV programs on the web. Social media, photos and young people's Internet behaviour exploded. Internet is a service that is generally accepted in society. Mobile internet in smart phones for surf, music and mail is generally used and taken for granted. Swedish ministries are active on twitter and social media and use Internet as a tool in their daily work.

Vinnova has made a study of the ICT area [1] involving a total number of 2 700 companies. Together these companies have 130 000 employees distributed over 4 300 different workplaces around Sweden. Given that the study uses the full-time equivalent as a measure to quantify the number of employees, the number of persons employed in the sector is considerably higher, approximately at least, 160 000. Despite the important economic recession, the companies register an almost 13 % increase in employment during the past five years. The expansion is most notable among the consultancy and the software companies. In addition about 100 000 additional employees work with ICT related tasks in other non-ICT areas, such as automotive and automation industry.

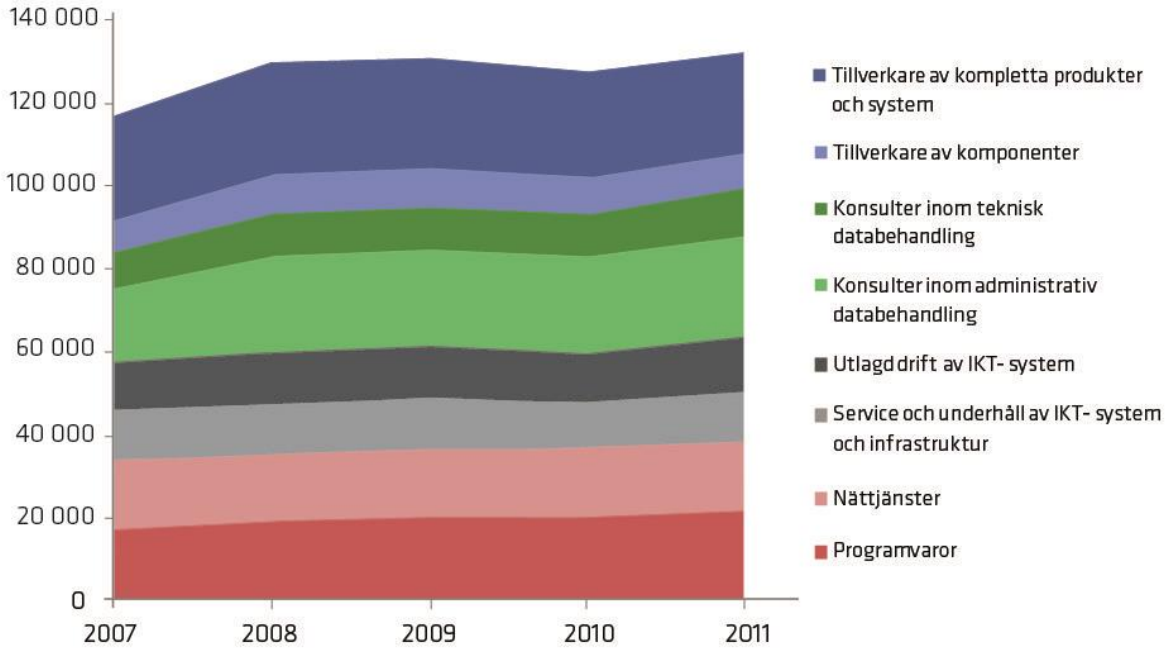

Figure 3: Vinnova report [1] shows employees growth over time in different sectors of ICT development

Many Swedish companies depend on innovative and effective ICT solutions to maintain their competitiveness [5]. There is no sign of decreasing investments. Investments need to increase with growing system complexity and the fact that more and more product functionality is implemented in software. Hence, ICT represents a significant amount of business investments requiring return in terms of innovation, increased revenue and growth.

- **Aerospace** develops safety critical systems such as flight control and vehicle systems implying high levels of system and software complexity. In addition, better human-machine interface for displays and controls are becoming more and more important.

- **Automation** ICT increasingly replaces mechanical systems. Increasing complexity and, at the same time, a demand for safer systems with better usability requires competence and smart ways for developing robust systems according to the growing needs in this area.

- **Automotive software** controlled and communication enabled functions provide for 90% of innovation and pave way for green propulsion, active safety and additional in-vehicle services. This trend drives the need for new architectures, methods and techniques, as well as competences to efficiently deal with the functional growth, safety and configuration management.

- **Telecom** Large scale development including the management of legacy systems, continuous deployment and enhanced performance by means of multi-core technology are a few examples of the current needs, requiring a mixture of technological solutions for addressing them effectively.

- **Media** An increasing reliance on ICT in their production and distribution of image, text and video, in an integrated landscape of the internet, TV, radio, newspapers, has triggered needs for effective development and management of heterogeneous distributed systems.

- **Music, film and gaming** industries rely heavily on advanced software and communication systems for production, marketing and distribution of their products and services in a fast changing environment, demanding improved technology, processes and methods supporting their lifecycle and its management.

- **Emerging non-traditional ICT dependent** industries such as mining and forest industries, with an increased need for automation and decision support systems drive the need for understanding the structural and technological changes implied by increasing software reliance

There are many examples of Swedish industries with large ICT content that are successfully engaged in the global market, several of them are part of this innovation agenda. However, International competition is toughening. Competition from countries, e.g. China and India, with a more favourable cost structure is also constantly increasing. Therefore, Swedish industry must renew itself, its products and services in an increasingly faster pace. ICT enables the industry to renew, expand and strengthen its innovation ability across many sectors.

Over time, Sweden has also gained great successes with a growing number of companies using software to break into the global markets with their innovations. For instance, Klarna AB, which was founded in 2005, employed almost 800 people in 2012 and is aiming at 1600 employees in the next years. Spotify, founded in 2006, doubled its work force from 177 to 300 employees between 2011 and 2012 and presented an annual turnover of 1.1 billion SEK. Rebtel, with a 383 million SEK turnover in 2011, is another flourishing example. In addition, the acquisitions of TAT by RIM/Blackberry, Scalado by Nokia and PolarRose by Apple are only a few examples clearly indicating that international players endorse the Swedish software skills.

Another example of the importance of software comes from the European automotive industry, where the value of software is expected to increase from 127 billion € in 2002 to 316 billion € in 2015 [2]. This clearly shows that traditional hardware-intensive companies have become software companies in a relatively short time. Other innovations by Swedish companies include colour screen, pacemaker, mobile phones, active safety systems for cars, Skype, Minecraft, Blocket, mobile broadband etc.

Looking forward, we see that in addition to the industry perspective, there are a number of important trends from society at large that will impact and motivate work towards the goals of this agenda. The Internet is more and more becoming an integral part of our everyday life and of many businesses. Society is becoming increasingly dependent on Internet and IP-based services. To meet these demands, practices and strategies are needed for handling breakdowns and emergencies. Infrastructure and services need to be robust to disruptions and stress; communication and services need to meet increased demands on availability, integrity and security.

Data traffic growth in mobile and fixed networks has during the last years broken all previous records. The growth is enabled by increased bandwidth of both fixed and mobile networks and driven by the demands from new services and applications, in particular TV and video. Optical fiber connects more and more homes, buildings, and base stations etc, providing the necessary bandwidth in access, backhaul and core networks. Traffic is increasing in all network segments everywhere.

Last but not least, the global warming is a universal concern applying to all areas, including those connected to ICT as described in this agenda. The EU has identified climate change as the most important challenge of our time. The ICT sector has a leading role in combating climate change, reducing carbon emissions via two different mechanisms:

1. ICT-solutions provide a great potential for contributing to sustainable development in many other sectors, through new business models, improved monitoring and control of activities and processes. Innovation, research and policy-making need to support this in order to make it possible to reach the potential.
2. Reduction of ICT industry's own carbon footprint, which accounts for a relatively small but growing part of the global energy consumption. Computing and Network capacity needs to be scaled up without the cost and energy consumption scaled in the same way.

3 Vision

Sweden is the innovation center for development of competitive, usable and sustainable products and services enabled by ICT.

Beyond the year 2020, we envision that Sweden is the world's most sustainable society where the entire population, companies, schools and government, all have access to the world's most advanced ICT infrastructure which has dramatically reduced its energy consumption compared to today. All of Sweden is covered by mobile broadband, and more than 1000 million "things", including, meters, sensors and vehicles are connected to the Internet.

This high performance ICT infrastructure supports Sweden's main industries to be competitive on a world market. Being ubiquitous, it supports tourism, forestry and mining, as well as being the main carrier of critical societal communications services for emergency systems, banking and media broadcast. Traditional industry such as automotive and automation is strengthened by advanced use of ICT since it enables products and production to become more energy efficient. This unique ICT environment not only creates growth through new and established Swedish industry but also by a steady stream of international world-leading ICT companies that choose to locate their operations to Sweden.

Sweden has the world's best-developed population in digital media and ICT [11] and the country serves as a test bed for new digital products and services. In this unique environment, new business models are created and new world-leading innovative product and service companies in the digital area, form, thrive and grow.

Smart grids, intelligent electric power grids, which can balance electric power production and consumption based on cost effectiveness, reliability and environmental friendliness will be a reality.

ICT is one of the keys for enabling sustainability in products and services. Optimization of everything from combustion processes and transport systems to food, water and usage of natural resources are all enabled by ICT.

Swedish health care has dramatically increased the integration of ICT in usage, services and equipment. An increasing part of the health care is handled by home diagnosis and home supervision of patients. The welfare society for an ageing population is maintained.

Underpinning all ICT activities is software. Whilst it is difficult to predict the precise operating environment for software in 2020 and beyond, it is expected that [8]:

- An increasing reliance on software-driven artefacts will require software as infrastructure; i.e. software that is "always-on".
- Most software will run on distributed, heterogeneous and highly parallelized systems.
- Such systems will have to operate in environments, which are open-ended and only partially observable.
- Requirements will change during the lifetime of the software requiring that it is evolvable and adaptable.
- Complexity will increase dramatically for each new project.
- Integration and testing of legacy software, open source and other third party software are issues in dire need of new levels of understanding.

- Software components will be combined in such a way that the resulting solution will provide new functionality emerging out of existing software components and services.
- Software quality will be increasingly important.

The vision of this agenda has three underlying objectives, the ABC objectives, which govern the activities in the roadmap.

Advance

- Advance existing efforts, resources and facilities by assembling them as collective, resourceful and dynamic joint ventures focusing on accommodating the prioritized national and cross-industrial needs.
- Spread the results in ways that guarantee extensive value gains for all stakeholders in the innovation system.

Boost

- Strengthen Swedish ICT skills and competence supply.
- Boost children's and youngsters' interest and attraction to ICT development.

Create

- Create 1000 new Swedish ICT companies with at least 100 employees by 2020.
- Increase the number of ICT developers by 100% by 2020.

4 Roadmap to the future enabled by ICT

To identify the full range of changes that organizations make to improve performance and their success in improving economic outcomes requires a broader framework than technological product and process innovation. The inclusion of marketing and organizational innovations creates a more complete framework, one that is better able to capture the changes that affect firm performance and contribute to the accumulation of knowledge.

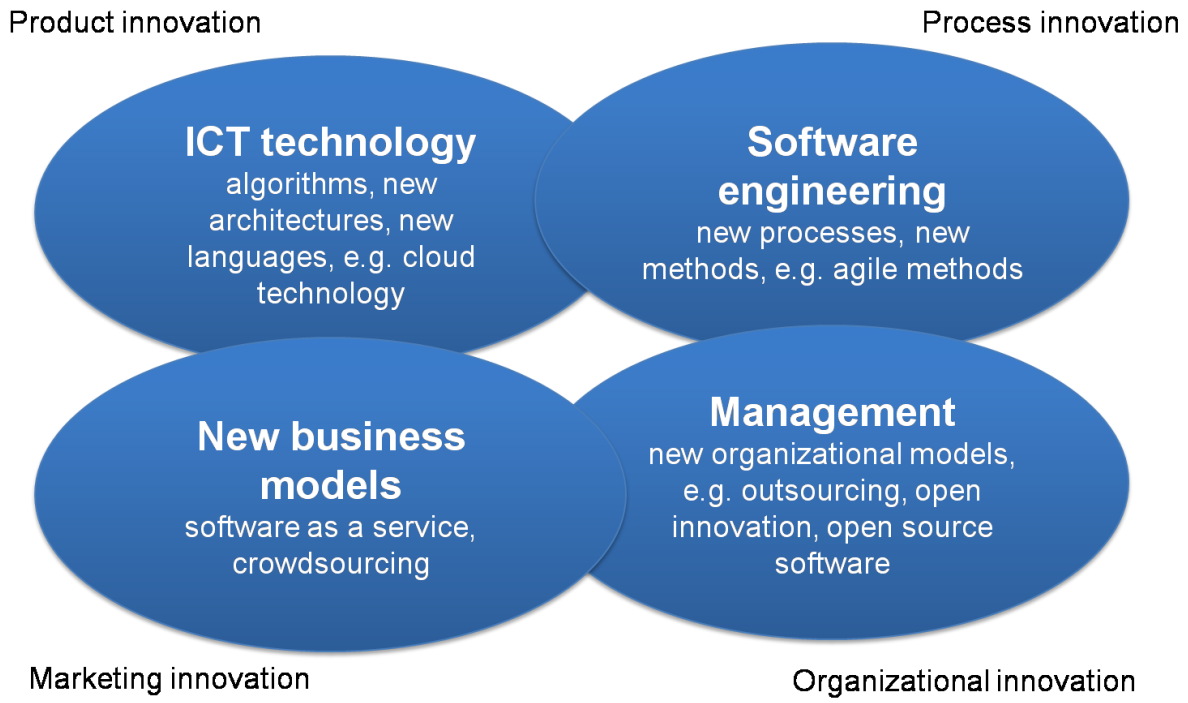

Figure 4: Guidelines for Collecting and Interpreting Innovation Data, OECS 2005 [9]

A **product innovation** is the introduction of goods or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics.

A **process innovation** is the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software.

A **marketing innovation** is the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing.

An **organizational innovation** is the implementation of a new organizational method in the firm's business practices, workplace organization or external relations.

Software, with its intangible characteristic, is particularly feasible for this innovation framework. Software innovation happens at the crossing of these different types of innovation. For instance, Klarna AB has introduced a new business model (payment mediator) by combining new engineering methods with advanced technology (Erlang).

Common requirements for all future products and services, independently of their origin, are that they have to be secure and environmentally sustainable.

4.1 Systems of Systems

There are a large number of enabling technologies related to ICT. As part of the Swedish ICT strength areas there are some specific enablers selected based on industrial needs in combination with important research being carried out in Swedish academia. To enable the potential for these solutions to contribute to societal goals on environmental performance and sustainability, interdisciplinary research in close collaboration with stakeholders are also a key.

Ubiquitous connectivity among devices, systems and systems of systems provides unprecedented opportunities for innovation. Big data and analytics, Internet of things and Cyber Physical Systems constitute key areas that embrace and provide enabling technologies for cost-efficiently making data and functionalities available, and for creating added value services, thus providing a foundation for the 21st century industry, as written in a recent report to the US president [12]. Investment in these areas underpins all design and manufacturing industries as well as health care and infrastructure.

4.1.1 Big Data and analytics

There is an enormous potential - commercially, societal and environmentally - in the analysis, modelling, and visualization of the huge amounts of data that now permeates today's society. Although capacity to store, distribute and search large data sets exists today we are still a long way from realizing the full potential of this information, and data and the ability to extract useful information from it will arise as one of the most important competitive factors during the next few years. Further, Big Data and analytics will serve as an enabler for both smarter end-user applications and services and efficient management of large-scale systems such as transportation networks or energy grids, and is a key component in the push towards autonomics in the large, heterogeneous, and complex systems of the future, including communication networks, cloud services, transportation systems, trade and finance, and energy management.

Within Big Data and analytics, a number of longer term challenges need to be addressed to reach the full potential of available data. First, the current push to make use of and analyze all available data naturally leads to new challenges within storage, computation, and networking; but also necessitates the development of stream-mining algorithms that can extract information without storage. This also means that Big Data analytics will happen everywhere - pushed out to our devices and into the network infrastructure due to the fact that data volumes are too large to centralize and too sensitive to distribute in their raw form. As most of this data is unstructured, a significant effort towards development of appropriate analysis methods is also necessary.

Second, by making data and analytic services more available to potential users and services a new service and exchange market for data analytics can be created, enabling applications and businesses not seen before. This however requires development of business models, incentive structures and methods for managing privacy and integrity issues. In all, it is likely that in the next few years there will be a change in the way ICT infrastructure is managed, shifting the focus from connecting machines and computation to services and how to manage and extract information from data.

Sweden is currently in a strong position to realize this potential. Swedish companies as well as the public sector generate and collect data sets of high quality; the ICT and business infrastructure supporting Big Data applications is relatively mature in Sweden and Swedish companies; and there is a strong research tradition within critical areas such as data analysis, cloud computing and networking. However, it is critical that we now leverage on these strengths. To do this, we must create directed support for research and infrastructure around Big Data, which would enable applied research within several levels of Big Data and analytics; develop common standards and national test beds to enable a

business ecology around Big Data; and ensure that we have a secure competence supply from universities within Big Data and analytics.

4.1.2 Internet of Things

Internet of Things, IoT is the name for the combination of technologies and ecosystem providing new innovative products and services through the possibility to connect everything allowing exchange of information. IoT will enable significant change and growth of business from all fields related to business logic, business processes, services and operations. Technologies like RFID, short range wireless communications, real-time localization, and sensor networks are becoming increasingly pervasive, making the IoT a reality for services and products in industry, health, transportation, gaming, energy.

The combination of sub-technologies, methodologies and business models will enable sustainable and cost effective roll out of various services and products related to IoT:

- Eco systems for products and services relying on IoT technologies
- Secure service management
- Secure and sustainable communication architectures supporting robustness
- Sustainable low power and energy consuming hardware, software and communication protocols
- Adaptable services and products based on user experience

By defining a set of reference architectures serving different demands for various services and products the threshold and time to market for new innovations can be significantly decreased. Standardisation of communication and management based on these reference architectures will further strengthen the growth enabled by IoT.

4.1.3 Cyber Physical Systems

Cyber Physical Systems (CPS) use computations and communication embedded in and interacting with physical processes to add new capabilities to physical systems. In a CPS, computers, networks and the devices and environments in which they are embedded have interacting physical properties, consume resources, and contribute to the overall system behaviour. They are in-fact so tightly integrated that it is not possible to identify whether behavioural attributes are the result of the computer parts, physical laws, or both working together.

These Cyber Physical Systems range from tiny (pace makers) to nation-scale (the power-grid). The large scale deployment of connected computer-augmented devices implies that “all” devices and systems can potentially be “sensed”, connected to computations and used for services. CPS is therefore a huge source of economic leverage and can be applied in a wide range of domains, for example:

- Transportation: Highway systems that allow traffic to become denser while also operating more safely. Automobiles that are more capable and safer but use less energy. Automobiles that refuse to crash.
- Energy and Industrial Automation: New and renewable energy sources. Homes, office, buildings and vehicles that are more energy efficient and cheaper to operate.
- Health and Biomedical: In-home health-care delivery. More capable biomedical devices for measuring health. New prosthetics for use within and outside the body. Networked biomedical systems that increase automation and extend the biomedical device beyond the body.
- Critical Infrastructure: A national power grid that is more reliable and efficient.

The tight interactions and networking within a CPS also pose strong challenges relating to how to deal with the multitude of heterogeneous interactions, dependencies and properties. Although the 20th-century science and technology has provided us with effective methods and tools for designing both computational and physical systems (e.g. through mechatronics, computer science and systems engineer), cyber physical and larger scale embedded systems have so far been developed in a rather ad hoc manner leading to costly development and barriers to the types of systems that can be effectively engineered. Progress is required in many areas.

The agenda will focus on design methodologies, reference architectures and model-based engineering technologies that support the multiple involved competences enabling virtual development, efficient verification, system evolution and maintenance. Key properties include performance, openness, robustness, safety, security, availability and evolvability. The agenda will also focus on new business models that may be required, and enabled, by the shaping of new systems of systems.

Sweden is currently in a strong position to realize the potential of CPS, with strong cross domain industrial sectors and universities. To leverage this position, new multidisciplinary research, cross domain collaboration (SoS implies new constellations of stakeholders), common test beds and promotion of standards will be required.

4.2 Communication Systems

Internet traffic is increasing rapidly. This is driven by increased bandwidth of both fixed and mobile networks and the demands from new services and applications, especially media based, including social networking, content delivery, cloud computing, and emerging machine to machine (M2M) communication applications.

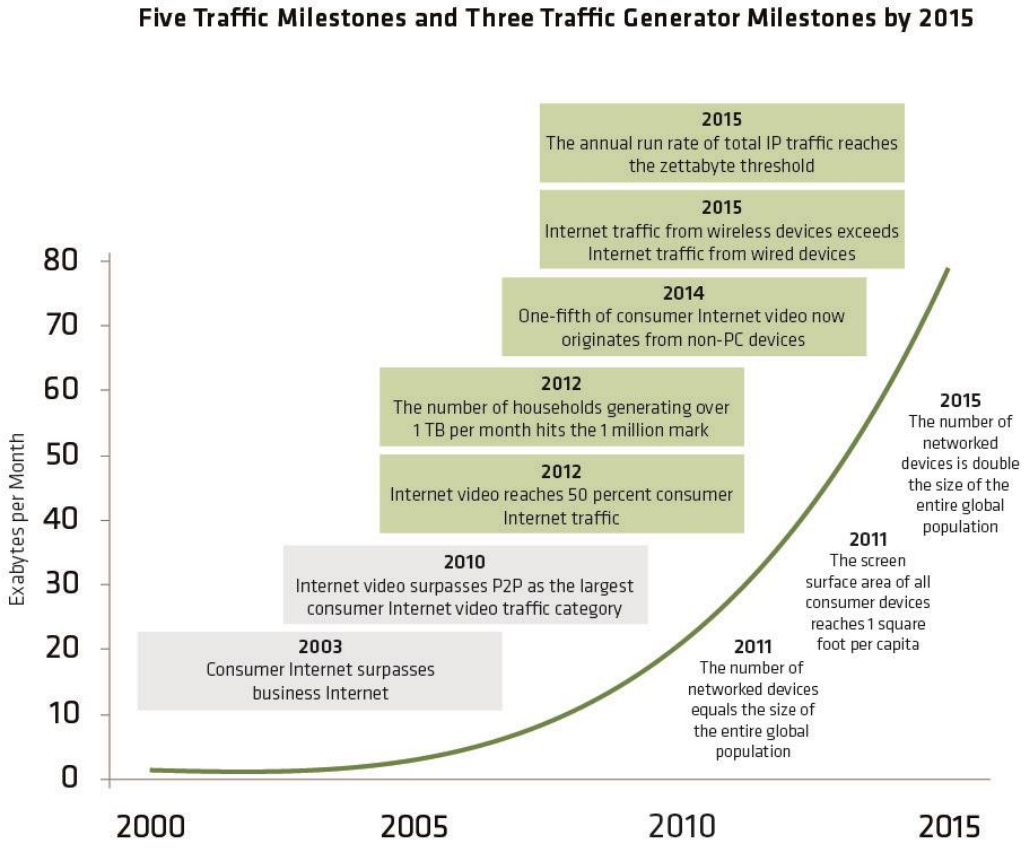

Figure 5: Cisco predication [3]

4.2.1 Media and content distribution

The increasingly dominant media and other content distribution applications motivate developing new network mechanisms. Content distribution networks (CDNs), transparent web caches, and peer-to-peer (P2P) overlays are common mechanisms that add caching functionality to the current infrastructure. These network mechanisms improve network performance in terms of capacity and delay driven by demands from applications in media and content distribution. The mechanisms also have a great potential to contribute to the overall network efficiency in terms of energy and cost.

With the same motivation, information-centric networking (ICN) is proposed as an approach to designing the future network infrastructure. The key concept is that the data is independent of where it is stored. Thus, any device that has a copy of the data object can satisfy a request for it. Initial simulation and modelling works have suggested that ICN can offer significant gains in performance. Furthermore, developments in parallel data flows implemented as multipath or multi-source connections can leverage the ICN concept ever further.

Caching is a key technology for improving performance and efficiency, both in the ICN and non-ICN contexts. The placement of caches and the distribution of data objects are however of utmost importance in order to optimize performance. Akamai, for instance, deploys caches at the edges of the network, increasingly closer to the end user to keep latencies low. Understanding caching behaviour is complex, there are e.g. many time-dependencies as the popularity of different data objects will change over time. Also spatial differences in the objects will occur, the language of the content, affecting its locality. The network topology will be a major factor in quantifying cache performance, as well as many other factors.

4.2.2 Control and Management

The growing complexity and heterogeneity of networked systems, with rapidly growing numbers of network elements operating under highly dynamic and unpredictable conditions, virtualized network connections, and a closer integration with storage and computational resources, pose new challenges to control network management in terms of scalability, resilience, security and adaptability. In order to meet these challenges, new approaches to management must be considered.

To reduce the need for manual intervention and to provide the expected QoS for products and services spanning from traffic and industrial systems to media and content, future network management solutions need to be self-maintaining and highly decentralized. This is in line with earlier work on distributed, self-, and In-Network management solutions, and represents the current trend in network management research. It is, however, becoming increasingly apparent that network management techniques must also begin to address and manage the inherent uncertainty in complex networks. To efficiently manage network resources and the inherent uncertainty of the actual network state, we claim that such systems must adopt the concept of probabilistic network management, in which management algorithms make management decisions based on probabilistic objectives, agreements and estimated network performance probability distributions, rather than on deterministic performance guarantees and measured averages.

Further, approaches to making management easier, flexible and more standardized through decoupling the control plane and the data plane are rapidly gaining ground through the development of Software Defined Networking (SDN). Widely deployed in data centers and cloud computing, SDNs make it easy to quickly provision network connections without detailed policy control and could transform traditional networking to better handle network virtualization, mobility, and growth in traffic. However, to realize these potential, current implementations, standards, and management systems need to be developed to the point that they fully scale to carrier grade systems.

4.2.3 Energy efficient networks

Mobile networks enable end-user mobility; fixed networks provide the necessary bandwidth in FTTH, backhaul and core networks. This is not going to change, optical and mobile networks operate in symbiosis to enable the future Internet, and this will be done via a higher integration between the different network technologies and the service layer, e.g. orchestration between cloud services, data centers and converged networks that connects these and their users.

The fundamental bottleneck of mobile broadband is the limited availability of radio spectrum. The current pace of expansion is not sustainable, unless radical inventions are made that improve the efficiency of spectrum utilization and reduce the energy expenses. Entirely new technology needs be invented and developed; promising directions are massive multi-antenna arrays, billboard antenna arrays and optical wireless technology.

The backhaul network that supports common transport of residential, enterprise and mobile traffic is a key part in the future communication infrastructure. This converged network should provide capacity and energy efficient, massive roll-out of mobile broadband. This network may consist of a flexible optical layer, integrated with the IP-layer as part of a programmable network. Network planning and dynamic capacity allocation are important techniques to develop for energy efficiency, both in the radio and the backhaul segments.

In order to create a sustainable and cost efficient end-to-end transmission infrastructure which supports the steadily increasing capacity demands from the (mobile) access it is imperative to utilize the existing optical fiber infrastructure efficiently. Here the use of coherent optical communication systems is key. In research, resulting fiber capacities of more than 100 Tb/s for thousands of kilometres transmission have been demonstrated.

Commercial systems are under current development. Sweden has traditionally a strong position in this area both within basic system research as well as in performing advanced field trials (test bed for core networks). It is of significant importance to maintain the Swedish position also in the future in order to support competence wise Swedish fixed and mobile system vendors as well as telecom operators working nationally as well as internationally.

Another direction where we have just seen the beginning, both in terms of technology development and in terms of applications, are large scale deployments of wireless sensors as a part of internet of things. The technology bottleneck is the limited energy supply which puts hard requirements on the power available for communication. All communication layers have to be optimized for supporting those ultra-low power requirements. For some applications originating from RFID there are an enormous latent potential to be deployed at a much larger scale than today. The adoption of new radio spectrum, primarily in the millimetre-wave band, will fuel the development described above. Sweden is a leader in the radio access technologies field and is well positioned to take a leading role in this development.

4.3 Software

Sweden is a world leader in the development and research of certain classes of software. A class of software is distinguished by the fact that it is applied in many areas that have similar demands on its quality. For instance, safety-critical software is a class of software that is found in a variety of computer systems and products, regardless of trade, industry or sector, i.e. aerospace, automation, automotive, telecom, media, gaming and healthcare. Many of these examples include software issues that are addressed in each of the trades, and there is a significant potential for cross sector knowledge transfer and innovation.

4.3.1 Complexity

New infrastructure allows heterogeneous systems to be connected to each other. Therefore, there is an urgent need for systematically derived knowledge on how to develop and maintain systems, based on integration of other systems, possibly provided by other actors in various forms, such as suppliers, subcontractors, or open source communities. The life cycle of systems and components may be counted in decades, surviving technological generation shifts. Important aspects of knowledge required for these systems of systems involve decision support for make/borrow/buy decisions, knowledge of distributed systems, refactoring of deteriorating legacy systems and quality assurance. On the other end of the scale, knowledge is needed for start-up companies, building their software systems to be adaptable and possible to integrate with other systems, without spending effort on developing features that are not needed at the moment.

4.3.2 Dependability

Safety critical implies systems where errors can be highly interruptive or even harming people's safety and lives. Consequently, developing such systems involve care for correctness, redundancy, reduction of complexity, and a significant amount of conservativeness regarding technologies and processes. In short they need to be dependable. Verification should also be considered an important area that needs to be addressed. Safety critical parts of a system are traditionally physically and logically separated from other parts of the system, to reduce the complexity and the need for costly safety assessment of the complete systems. However, as demands grow for more advanced features, more integrated systems of systems, and faster pace of change, also for safety critical software, the technology and engineering practices must advance to ensure competitiveness. Although different industry domains, e.g. aerospace, automation, robotics, automotive, are regulated by different safety standards, the standards share certain core properties that enable joint research and development across domains of new development practices for safety critical software-intensive systems. Dependability will also address the need to make systems secure from cyber-attacks and other aspects of securing data, be it personal or other.

4.3.3 User experience/human factors engineering

For market driven software systems, the user experience is a key selling point for many customers. In gaming and other entertainment systems, it is the selling point. However, for in-house systems, and industrial type systems, the user experience may be a key contributor for the productivity gain expected by the system, and also a safety aspect in e.g. medical systems. As many systems are developed based on new technology push, rather than user pull, there is a significant risk that they are designed from a technical rather than a design perspective. User experience goes beyond user interface and user interaction design; rather it is about the conceptual models for interaction with the system and, when considering systems of systems, the modes for composing and configuring such systems, whether it be conducted by system integrators, or the users themselves.

At the intersection between traditional industry domains and the entertainment sector, and influenced by the "Scandinavian design" tradition, there is a potential to develop new user experience models. This may also include simulation systems for training to handle complex systems of systems. However, because this in not only an interface and interaction issue, deep architectural design competencies must be involved in this exploratory endeavour.

4.4 Competence supply

Prerequisite for innovation is availability of diverse competences forming holistic perspectives. Through collaboration in education, research and development there are a lot of gains; feedback to education and continuous learning development organizations, attraction to education, research and development for the individuals and an international exchange with a positive margin giving an inflow of competence to Sweden.

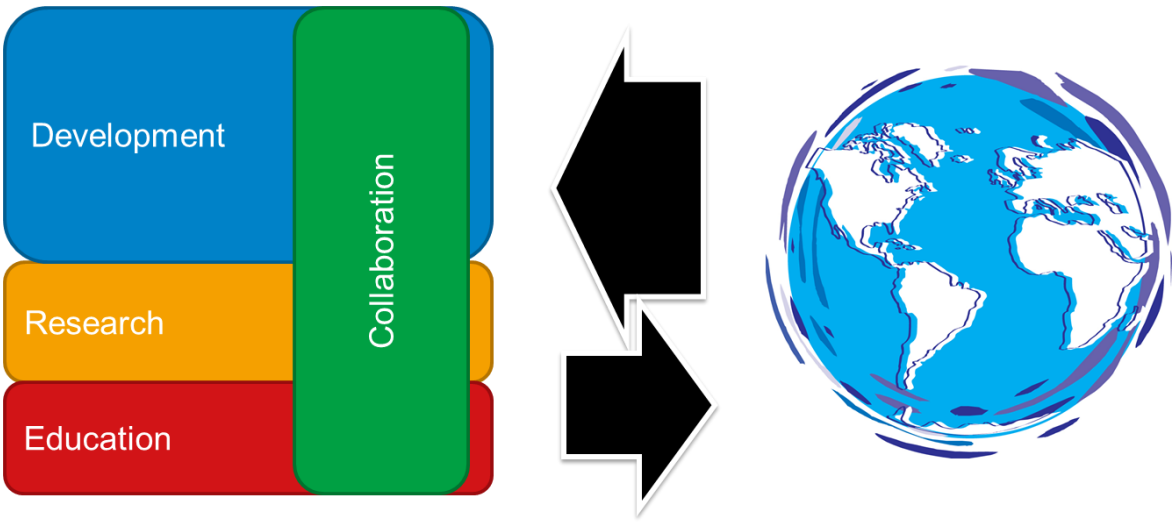

Figure 6: The flow of competence

The long-term supply of expertise, we can only achieve by getting young people in Sweden interested in technology and innovation early, already in elementary school. Many young people do not understand what engineers do. The engineer needs to be presented as a hero in the media. Good examples of this are TV shows like "Felix stör en ingenjör", Jan Guillou's recent book about "Brobyggarna", Ny Teknik's series "Under skalet". It is important that young people are not just users of technology, but also get to try to develop simple applications. With ICT being such an important part of our lives we believe programming knowledge should be taught at a much earlier stage. We see a great opportunity to join forces with the newly established "matematik kommissionen" [10] to introduce logic and programming in grade school.

Emphasize what engineers do and achieve e.g. that they are well placed to deal with many of the challenges related to energy and the environment. One program planned will create a "speaker pool" with highly recognized engineers from industry that can visit schools and do PR for ICT development.

Master educations need to be updated and complemented by addressing the Swedish strength areas described in this agenda. Continued education can be achieved by e.g. PROMPT which is a national competence initiative coordinated by MDH and with the following additional academic partners: BTH, SICS Swedish ICT and Chalmers/GU, which together with a large number of industrial partners (including ABB, Ericsson and Volvo) plan to develop a set of Software Engineering related master level courses that will be offered to industrial practitioners in formats that will allow them to follow the courses relatively independent of time and location. Furthermore, awareness of sustainable development challenges and the possibilities for ICT to contribute in a positive way as well as the risks for a negative contribution needs to be introduced into the education. This is for example done at KTH in the education programs for information technology and for computer science and engineering.

Foreign students who after graduation would like to stay in Sweden are an important resource in the short term, but also in the long term. We need to eliminate some of the barriers that exist and offer carrots for them to stay. Even if they eventually return we should ensure that they would bring good memories of Sweden and then could act as ambassadors. This also applies to foreign experts that need to stay in Sweden for shorter or longer durations.

The technical progress is rapid and it is necessary to provide persons working in industry for a long time with supplementary education which will help them to develop new services within ICT in their traditional industries. Life-long learning is a must in our fast evolving society.

4.5 Innovation network

Innovation often occurs in the meeting between people with different backgrounds, business and different actors in the innovation system such as industry, institute and academia. We propose a focus on achieving such a community through different physical meetings, as indicated below, to promote an open and innovative atmosphere and network. The scope can be anything from a seminar to a major development project.

Doctoral school for Ph.D. students shall be arranged to provide meetings points across technical domains. Summer schools are arranged to attract engineering students to the ICT area and let them meet researchers as sources of inspiration.

One form of cooperation is focus groups, small groups of specialists from both industry and academia who together discuss various technical issues and share experiences. Sweden has many major companies which should be able to share their skills to other companies that are not direct competitors. Typical topics should be in the areas of strengths identified in this agenda. Also R&D managers have this need to meet colleagues across company borders.

Industrial Ph.D.'s and licentiates give companies access to the latest research results and act as a glue which strengthens the bond and removes the barrier between companies and academia. A strategic mobility of personnel between companies and academia should be both ways and is sound to both parties.

Open labs or industry as lab – pilot projects are different challenges which need a broad system perspective and require that researchers from multiple disciplines work together. Industry can serve as an "integrator" (this method has been successfully applied e.g. by the Dutch Embedded Systems Institute) [6]. The projects shall preferably be long enough to facilitate Ph.D. students. An example of a pilot project where several Swedish universities (KTH, Chalmers/GU and Halmstad) have participated is the Grand cooperative driving challenge – convoy driving of vehicles to reduce fuel consumption [7].

Possibilities for the community to influence the agenda shall be arranged biannually, preferably combined with a conference.

In anticipation of the increased significance of software, internationally recognized research in software engineering has been built up at several Swedish universities during the last two decades. For instance, several Swedish professors and academic researchers are among the most cited in the field. Industrial Excellence Centers, such as EASE at Lund/BTH, ICES at KTH and Software Center at Chalmers/GU add to the Swedish current assets. This position of strength could be utilized as a backbone for competence development and collaboration. Several major industrial players have also established cross-sector collaboration, as well as industry-academia collaboration through the

organization Swedsoft, which through its members organize a majority of Swedish software intensive companies. We intend to develop Swedsoft to cover other stakeholders, both within industry and public domains, where software is a central part and to act as a coordination center for the software development activities of this agenda.

Start-ups and SMEs (small and medium sized enterprises) deserve special attention. We will actively recruit such companies to all activities in this agenda in addition to programs that speak to their special needs. One such area is procurement by governmental agencies. Today's regulations favour large companies and established technologies. We will work for the establishment of strong pre-commercial procurement.

Programs will be designed to provide support for the technical incubators for start-ups, providing software competence for new and growing companies.

Demonstrators are a proven tool for experimentation and collaboration. For all relevant areas we will investigate the need for demonstrators that can be used by both academia and industry.

International collaboration is important and we intend to actively take part in the Horizon 2020 framework program.

5 Abbreviations

Abbreviation	Explanation
4G	4th Generation mobile communication
5G	5th Generation mobile communication
CO2	Carbon diOxide
CPS	Cyber Physical Systems
EU	European Union
FP7	Framework Program 7
FTTH	Fiber To The Home
ICT	Information and Communication Technologies
IETF	Internet Engineering Task Force
IoT	Internet of Things
IP	Internet Protocol
IPv6	Internet Protocol version 6
LTE	Long Term Evolution (synonym to 4G)
TCP	Transmission Control Protocol
WWW	World Wide Web

6 References

1. Företag inom informations- och kommunikationsteknik i Sverige 2007-2011, Vinnova April, 2013
2. Dannenberg, Jan and Kleinhans, Christian: The Coming Age of Collaboration in the Automotive Industry. In: Mercer Management Journal, No. 17, 2005, 88-94
3. Cisco Visual Networking Index: Forecast and Methodology, 2011-2016
4. Service Innovation agenda, Vinnova diarenummer 2012-01857
5. Hårdvaruagendan "Elektronikhårdvara i Sverige", Vinnova diarenummer 2012-01870
6. www.gaudisite.nl/IndustryAsLaboratoryAppliedSlides.pdf
7. www.gcdc.net
8. ISTAG, 2012 "Software Technologies - the missing key enabling technology", IST Advisory Group (ISTAG)
9. OECD, 2005 Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data© OECD/European Communities 2005. ISBN 92-64-01308-3
10. Matematik Kommissionen www.mattekommissionen.se
11. Global innovation index report, INSEAD, 2012 www.globalinnovationindex.org
12. "REPORT TO THE PRESIDENT AND CONGRESS DESIGNING A DIGITAL FUTURE: FEDERALLY FUNDED RESEARCH AND DEVELOPMENT IN NETWORKING AND INFORMATION TECHNOLOGY" from President's council of advisors on science and technology – January 2013

7 Contributors to the Innovation enabled by ICT agenda

The following organizations, individuals and agenda projects have actively contributed to the content. For agenda projects only the project manager is mentioned, however in most cases the majority of related individuals and organizations have contributed direct or indirect through the agenda project manager. There have also been a large number of organized and spontaneous meetings and presentations with other organization and agenda projects not in the list below.

Agenda Projects:

2012-01836 Strategisk forsknings- och innovationsagenda för mjukvaruutveckling – SICS, Jakob Axelsson

2012-01857 Tjänsteinnovation – utveckling av strategisk forskningsagenda – Marknadstekniskt Centrum, Staffan Movin, Peter Berggren

2012-01870 Elektronikhårdvara i Sverige – Acreo, Jan Andersson

2012-01882 Nationell satsning på optisk infrastrukturindustri för framtidens Internet – Linköpings Universitet, Robert Forchheimer

2012-01900 Big Data Analytics – SICS, Daniel Gillblad

2012-01907 Cyber Physical systems – KTH, Martin Törngren

2012-01943 Skalbar och heterogen infrastruktur för framtidens informations- och kommunikationsteknologier – KTH, Claes Beckman

2012-01945 IoT Sweden – IVA, Östen Frånberg

2012-01946 Informationssäkerhet och säker IKT – Lunds universitet, Ben Smeets

2012-01951 System simulering och simulatorer – Linköpings universitet, Lars Eriksson

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Ericsson – Ulf Wahlberg, Anders Caspár

HiQ – Lars Stugemo

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LTH – Per Runeson

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