MEDEA$^+$ Applications Technology Roadmap

Vision on Enabling Technologies of the future

MEDEA$^+$ Programme

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Executive Summary

Importance of micro- and nanoelectronics

Today the electronics industry is first amongst manufacturing industries. It generates more added value than any other manufacturing industry; its market size is $800 billion, even bigger than the automobile industry. Among the investments in industrial branches, electronics now account for 30%, versus less than 5% in 1960. At present ICT (Information and Communication Technologies) expenses for hardware and software represent more than one-quarter of the total expenses on services. Electronics equipment including safety, engine control and anti-pollution represents around 20% of the direct production cost of a car, and even more for high-end vehicles. Electronics also play a vital role in the transformation of our society: access to the internet, mobility and e-commerce contribute to removing social and cultural barriers and to bringing every citizen into the information age, with direct benefits on health care, welfare and environmental issues. ICT is transforming the way we live, learn and play.

There is hardly any innovation in electronics or in services without micro- and nanolectronics innovation; in 40 years, the cost of the basic function - i.e. of the transistor - has decreased by 30% per year; that's the learning curve. In 2003 the cost of 1Mb of memory is equal to that of a sheet of paper, whereas 30 years ago, it cost as much as a family house. In terms of duration and annual price decrease this development is unique in the history of the industry. The current state of technology makes it possible to predict this trend's continuation until at least 2020: seventy years after the discovery of the transistor there are no viable technological alternatives! Silicon-based technologies will remain the dominant forces for the realisation of electronics equipment. Electronics equipment containing semiconductors has more than benefited from these price-cuttings. In 1960 a colour television set cost as much as a car; in 2003 it costs 20 times less.

However, the mastery of the learning curve comes at a cost: 40% of the annual sales of semiconductor companies must be reinvested in R&D and production means. Since 1994, the R&D spending by the European microelectronics industry has steadily increased and recently the R&D expenses of the European semiconductor companies were close to 19%, one of the highest worldwide. The European R&D co-operative programmes launched as part of the EUREKA initiative JESSI, followed by MEDEA and MEDEA+, backed up the industrial efforts and became more and more important because of the increasing need for co-operation.

Importance of this roadmap for micro- and nanoelectronics

The use of roadmaps has become a standard part of strategic planning in various business processes of the industry. The microelectronics industry e.g. is a keen observer and follower of the ITRS (International Technology Roadmap for Semiconductors); in that roadmap the required competitive process technology development, including gaps, barriers and bottlenecks to be solved, is mapped out. The ITRS is basically a thorough and well thought through extrapolation of the current situation. However, it is much more difficult both to "extrapolate" and to "predict" what the market and/or the customers will ask for in the future because normally products and services are offered to the market (albeit after some times sophisticated market research) as a result of technological possibilities.

This ATRM (Applications Technology Roadmap) has been set up to try and reverse the paradigm of "offer and demand" by starting from the envisaged future needs of the end users. In doing so, this roadmap presents a new approach to enable a better prioritisation of investments in technology development for microelectronics applications.

Relevance of this roadmap for the future of MEDEA+

The purpose of this roadmap is to identify those enabling applications technologies that have to be mastered on time in order to satisfy the user needs in 2012 that have been identified as part of this roadmapping activity. These technologies should be far enough developed to enable mass production in 2012. The development of these technologies would then become the basis for future R&D programmes, in particular but not exclusively for MEDEA+ and its successors.

The scope of the ATRM is determined by the applications that originated from the scenarios that were written on the basis of the collected end-user needs. Many of these applications address areas that are part of the current MEDEA+ program, e.g. fixed and mobile communications, consumer electronics with multimedia and internet capabilities, automotive electronics with communication and engine management, smart cards and associated security and safety solutions. Other applications are dealing with new areas like health, education, comfort, etc. and are outside the current scope of MEDEA+. The relevance of these applications for the future MEDEA+ program has still to be determined.

Target group of this roadmap

This Applications Technology Roadmap is intended for a large variety of users:

- The MEDEA+ organisation to prepare future programmes and calls.
- Programme managers of collaborating consortia to create and tune new project proposals.
- Industrial managers to relate in-house roadmaps to a wider European view.
- Public Authorities to align their programmes to the identified industrial needs.
- Strategy and marketing managers in the covered application areas to check their future product strategy.
- Individual researchers in industry and academia to find new interesting subjects for research.

Approach followed

This Applications Technology Roadmap should serve as a link between the vision that has been created by the Core-Team and the R&D projects and programmes that are required to realise this vision. In order to create this roadmap a new methodology has been applied. Firstly, a Core-Team consisting of high-level technical managers from MEDEA+ companies, made an inventory of user needs in 2012 and consolidated these user needs into a *vision on life in 2012* by writing a number of scenarios. Next, as the actions that play a role in these scenarios can only be carried out if certain functions are available, an overview was created of those technologies that have to be developed in order to meet the requirements of these functions. Subsequently, these technologies were classified and prioritised. Finally, these technologies were textually described and visually mapped into a roadmap as an ordered function of time.

Roadmap architecture

The microelectronics (or semiconductor) industry serves a very broad market, usually Telecom, Consumer, Automotive, Electronic Data Processing, Industrial and Military sectors are distinguished. Many of the necessary technologies are required in more than one market sector. This overlap creates allocation problems in a technology roadmap. To avoid this and to come still to a sufficiently complete coverage of the major applications that are needed in 2012 according to the vision, a set of application environments was defined that shows a minimal overlap in technologies. This also presented an opportunity to deal in a separate sub-roadmap with the Common Infrastructure technologies. Allocation of technologies to application environments was done on the basis of where the strongest requirements for a technology would originate. Only by introducing such a roadmap structure a clear and unambiguous insight will be achieved in the relations between applications and technologies.

The four chosen application environments are the following:

- Within Reach:
  Applications literally within reach of the user and including in-body electronic processing and control systems for health maintenance .
- Stationary:
  Applications relating to electronic equipment fixed in a home or other environment.
- On the Move:
  Applications relating to someone "on the move", with a strong focus on cars.
- Common Infrastructure:
  The backbone supporting the other three application environments.

Each application environment has been subdivided into themes and sub-themes that are recognisable from a user perspective. Within Reach e.g. has been subdivided into energy, communication technology, wearable devices, user interaction and personal experience.

Major results

The main purpose of the ATRM was the identification of those enabling applications technologies that need to be mastered on time in order to satisfy the relevant user needs in 2012.

The Core-Team considers the following challenging areas as defining the major technologies that will have to be developed:

- An advanced communications infrastructure as an enabler of application products and services,
- The increasing architectural complexity of applications and required infrastructure resulting in a minimum set of applications specific “smart” platforms,

- The strongly increasing role of hardware-defined software and reliable applications software,
- The overriding importance of better user-tuned interaction capabilities of nearly all applications,
- The production and management of mixed-media content,
- The increasingly important role of international standards,
- The expected explosion of miniaturised sensors/actuators and the corresponding health-related personal applications.
- Energy generation, transmission, storage and consumption as major boundary conditions for applications,
- Security, safety and privacy issues penetrating into each person's life and becoming all-pervasive in both private and public domains,
- Security, safety and privacy solutions that can be trusted, and that offer e.g. new opportunities in digital rights management,
- Increasing comfort in mobility and transportation,
- Assistance and convenience in car driving,

The Core-Team has identified for Europe the following threats in becoming a leader in system innovation on silicon. The dominance of a small number of US companies in areas like microprocessors and software will make it increasingly harder for European companies to build up significant positions in related areas, in particular because these US companies tend to swallow up peripheral activities and, in doing so, enlarge their dominance. This danger might be aggravated by the fact that export licenses on advanced US products will become harder to get in view of e.g. the Homeland Security. This will in particular apply to products and services with security and/or privacy aspects. In these markets maintaining independence becomes a major issue for the European microelectronics industry. In areas like storage and display components, the dominance of non-European companies is such that European efforts and initiatives stand very little chance.

On Europe's own side it should be realised that the European R&D activities as a whole are less focused and for important new areas like nanoelectronics and biotechnolgy, much smaller than in the US. Moreover, R&D activities in the US lead much faster to new emerging business activities. It should also be realised that a major issue is the timely migration of systems know-how from systems companies to semiconductor companies.

It should be stressed that the level of public support for R&D in important areas like micro-and nanoelectronics is significantly higher in e.g. the US than in Europe.

On the other hand, Europe has various characteristics that could and should work to its advantage. In the area of Ambient Intelligence, Europe is well positioned to set infrastructure standards and European companies could use this to make a head start in the realisation of the Ambient Intelligence vision. Europe has a high level of research, both in some major multinational companies as in academia, in particular in some outstanding research institutes. European companies are more inclined than companies in other areas in the world to really join forces and co-operate in all kind of joint R&D programmes both at the national, international (EUREKA!) and EU level. Last but not least, the creation of one European market should of course in the first place be of particular advantage for Europe's indigenous companies.

Recommendations

The Core-Team considers the following recommendations of this document as the most important ones:

1. Sustain intensive innovative and leading edge research programs in mobile communications and in multimedia to capitalise on the leading European position in these fields. The *On the Move* applications technology roadmap has identified the need for platform-based architectures. These should support future multiple radio communication systems (Software Defined Radio platform) and they should bring the required processing power for future multimedia applications (advanced multi-processing platform). The platform concept should be based on the processor-families roadmap for reuse of software and software tools. Due to the R&D cost of the development of processor families, European semiconductor companies - but not only those - will have to join forces to foster such R&D co-operation in order to reinforce European leadership over time.
2. Set up a European position that leads to a world standard for an interoperability framework for digital home networks. It should integrate mobile devices and broadcast services in a secure and seamless way, relying on IPv6 as unifying protocol. Based on this framework, intelligent devices will then enhance consumer experience by privileged personalised access to brand-new highly valued content. The concept of home gateway should be taken up by standardising the interface between public and private networks. Apart from the home gateway, several bottlenecks related to the home network (device and service discovery, security, personalised access to content, etc.) have also to be addressed.
3. Develop an integral system for personal health care comprising a network of advanced, non-obtrusive wearable health monitoring sensors. Apart from these sensors, algorithms need to be developed enabling local intelligence in a PxA (Personal “for whatever” Assistant). This should use stored personal medical data and, if required, should have secure access to professional medical data bases and services. This recommendation stems from a user need for preventive health care which becomes increasingly important when getting older. Electronic wearable products, that regularly monitor the condition of a person, are a prime means to enable preventive health care.
4. Deploy a European initiative to arrive at a coherent set of standards enabling the interoperability of wearable devices. This is necessary in order to enable a leading European position in the development, production and marketing of wearable products. This is important as people will wear in the future more and more valuable electronic products that are expected to work seamlessly together even when made by different vendors. The set of standards should consist of the following key standards: a Wireless Body Area Network standard, a Plug & Play standard for sensors and a Secure Communication standard to connect to services.
5. Develop broadband wireline System-on-Chip and wireless platforms in order to support multi-standard access equipment to maintain European leadership in the access market. Development efforts should cover access technologies

(broadband wireline and radio techniques), protocol optimisation (access modes) and broadband content delivery support, in order to allow the deployment of high-throughput services and adaptive quality of service.

6. Set up an innovative technology construction kit for power semiconductors. Power electronics is a key technology for all applications and innovations in the professional and home environments (power supply, energy conversion, power generation…). A significant amount of energy saving may be possible in the future by designing efficient energy conversion systems and by reducing losses in the component itself. Japanese and US government realised this and react by spending an enormous amount of public money (in US indirectly via military research) to strengthen all power technologies (IGBT, SiC, SOI, embedded power, power packages,…). To maintain global competitiveness of the European power semiconductor industry on the technology side versus Japan and US and on the cost side versus China, the European industry has to face this challenge by setting up an innovative technology construction kit for power semiconductors. Only this enables cost/performance optimised technologies and highly integrated (logic/power) components, it reduces the technology cycle time and improves reliability. This action has to be industry lead. However this cannot be done by industry alone but is only possible with a strong engagement of public money based on an industry-wide co-operation in a vertical direction.
7. EU must maintain its independence in all segments of security products. EU cannot rely for its security on products provided by foreign countries, in particular on US products subject to export licenses delivered by the National Security Agency (NSA). This would imply that a US Agency (via backdoors) has the ability to decipher the data treated by these products, officially in the name of the struggle against terrorism. This is obviously true for networking products and trusted computing platforms. Even if EU does not want to develop its own microprocessor, relying on Intel, AMD, …, EU must develop an external TCPA component. This is necessary to replace the one embedded within the processor. And EU needs to keep the know how in computing platform design to be able to develop its own trusted computing platforms. If EU does not do so, there will be no way for EU industry (and trade) to maintain confidentiality of its activities and to lever its independence and leadership.
8. Develop flexible and scalable platforms for automotive electronic control units to meet the increasing demands for time to market and cost. This action includes microcontrollers of highest performance, alternative non-volatile memory systems, embedded power components, bus interfaces and architectures as well as visionary, cost-effective system packaging technologies. This action is essential to maintain European leadership in the automotive electronics segment, which is one of the last electronic domains with a quite strong European position.

Closing remarks

The ATRM as here presented is the official version 1.0 of the Applications Technology Roadmap of MEDEA+, for which the MEDEA+ organisation takes full responsibility. This version is by definition not complete or exhaustive, but as it is a living document, the MEDEA+ organisation is committed to a periodical update.

Finally, as owner and initiator of this roadmap, the MEDEA+ organisation would like to acknowledge the active support and contribution of those MEDEA+ companies that have been willing to appoint the members of the Core-Team, i.e. Alcatel, Robert Bosch, Bull, Infineon Technologies, Italtel S.p.A., Philips Semiconductors, STMicroelectronics and Thomson.

Scope of the Applications Technology Roadmap

The MEDEA+ Applications Technology Roadmap (ATRM) focuses on the ways and means to fulfil end-user needs in 2012 from an *applications* perspective.

The scope of the ATRM is therefore determined by the applications that originated from the scenarios that were written on the basis of the collected end-user needs.

Many of these applications address areas that are already part of the current MEDEA+ programme, e.g. fixed and mobile communications, consumer electronics with multimedia and internet capabilities, automotive electronics with communication and engine management, smart cards and associated security and safety solutions. Other applications are dealing with new areas like health, education, comfort, etc. and are currently outside the scope of MEDEA+. The relevance of these *applications* for the future MEDEA+ programme has still to be determined and they will possibly have to get more attention.

The MEDEA+ Applications Technology Roadmap covers the time scale until about 2012. The technologies, as described in this document, should be far enough developed to enable mass production in 2012.

The Core-Team of this roadmapping activity, consisting of high-level technical managers from a number of MEDEA+ companies, started its work in November 2002 by studying existing vision-related documents and roadmaps. These documents were created by organisations like ISTAG, EICTA, ITEA, STW/PROGRESS, etc. References to these documents can be found in Chapter 1. Next, the team collected foreseeable end-user needs from the above-mentioned documents and some other sources. Based on this collection and adding own knowledge and imagination, the Core-Team described its *vision on life in 2012* in a number of scenarios. These scenarios have formed the basis for the remaining roadmapping process, as described in the Introduction to the Applications Technology Roadmap and more extensively in Appendix 6.

The roadmap presented in this document is the major result of the roadmapping activity. It reflects the experience and opinions of the experts of the Core-Team, of the participants of the workshop, of interviewed experts and of internal as well as external reviewers.

As the scope of this roadmap is extremely broad, it is not and cannot be exhaustive or complete. Also the tight schedule of this roadmapping activity has caused a certain limitation in the end result. Moreover, a roadmap is a living document and needs to be updated regularly.

This Applications Technology Roadmap is intended for a large variety of users:

- The MEDEA+ organisation to prepare future programmes and calls,
- Programme managers of collaborating consortia to create and tune new project proposals,
- Industrial managers to relate in-house roadmaps to a wider European view,
- Public Authorities to align their programmes to the identified industrial needs,
- Strategy and marketing managers in the covered application areas to check their future product strategy,

- Individual researchers in industry and academia to find new interesting subjects for research.

Successful implementation of the roadmap depends, besides upon the realisation of the indicated technology challenges, also on general trends in society, business and the worldwide economical situation. These aspects are only implicitly covered through the end-user needs.

Finally, as will be clear from a close look at this roadmap, some of the identified *technologies* and described technology challenges are outside the scope of the MEDEA+ programme.

It should be stressed, however, that it is not the intention to enhance or broaden the scope of the MEDEA+ programme in any significant way, but it would have been an impoverishment of the value of this roadmap if we had deleted those technologies.

1 Introduction to the Applications Technology Roadmap (ATRM)

This roadmap presents information on the enabling technologies that in the future will be required to implement applications with micro-, and later nano-, electronics circuits. Applications is the general term used to indicate any type of consumer or professional system or piece of equipment that for the realisation of its functions depends on the use of (micro-)electronic circuits. Applications cover a very wide range, examples are e.g. radio, PC, DAB, smart cards, transmission systems, television, DVD, GPS, mobile phones, medical diagnostic systems, ABS, car ignition electronics, digital cameras, navigation systems, printers, lighting systems, battery chargers, server systems, refrigerators, etc.

As it is quite hard to foresee what future functionality will be required over such a wide diversity of electronic products (and the related services), a special approach is needed to come to useable results. This approach is described in the remainder of this chapter.

The introduction starts with a short overview of the major trends and other factors that influence the desirable applications and their enabling technologies. This is followed by a succinct description of what a roadmap is and how it comes about. Subsequently the new methodology that has been designed for this roadmap is summarised to highlight its major, unique characteristics. An overview of the major important themes of the four defined application environments concludes this chapter.

Influence of general trends on enabling technology requirements

In the advanced developed countries declining birth rates and growing average age will combine to increase the cost of health care and pensions, while reducing the relative size of the working population. Therefore continuing increase in efficiency/productivity will be needed. Electronics equipment is supposed to have a major contribution here e.g. by automating routine health checks.

Looking ahead until 2012, the world will face quantum leaps not only in information technology but also in other areas of science and technology. The continuing diffusion of information and new technologies, like biotechnology, will be at the crest of the wave in this period. The integration, or fusion, of continuing revolutions in information technology, biotechnology, material science and nanotechnology will cause a dramatic increase of possibilities. If accompanied by investments in technology the development of complete new applications will start and this will further stimulate innovations.

Biotechnology will drive medical breakthroughs that will enable the world's wealthiest people to improve their health and increase their longevity and quality of live dramatically. Breakthroughs in materials technology will generate widely available products that are multi-functional, environmentally safe, longer lasting and easily adaptable to particular end-user needs. Most of these will rely on electronics for their functioning and human interface.

On top of the above-mentioned “macro” trends, there are “individual” trends. The most striking one is individualisation. People are more and more aware of their individual rights, demands, wishes and feelings, etc. resulting in an increasing demand for mobility, ubiquitous connectivity and access to information, any time and everywhere. Families are also changing, negotiating more issues and relations at a distance, also as a result of a different composition of households. This also increases the need for travelling over longer distances and more telecommunications. Both result in many demands for applications providing or supporting more safety and comfort.

Due to globalisation of the business, the enormous possibilities of broadband and wireless Internet, the way of doing business and business models have been changed and will continue to change in the future. One can observe the introduction of flatter organizations, focus on core business, multi-site/multi-company co-operations, e-business, etc. and a shift from equipment manufacturing to selling services.

It is obvious, that the exact influence of all these trends on appliccations is difficult to predict, but it will undoubtedly result in a “sea” of new requirements, which differ from the traditional ones.

Impact of microelectronics

There can hardly be any innovation in electronics or in services without innovation in microelectronics. In 40 years the cost of the basic function, i.e. the transistor, has decreased by 30% per year. In 2003, the cost of 1 Mbit of memory is equal to that of a sheet of paper, whereas 30 years ago, it cost as much as a family house.

The current state of technology makes it possible to predict that this annual price decrease will continue until at least 2020. Silicon-based technologies will remain the dominant forces in next decade, there are no viable technological alternatives. So, the impact of silicon-based microelectronics on daily life will continue.

In 2002, the average silicon content in electronics equipment was 18%, versus 4% in 1977. The long-term trend points to a 6% annual average increase of this content (see [1]). In addition to the well-known scaling effect (Moore’s Law), continuous progress will be made possible by the use of complementary materials and innovative techniques, like “nanotechnology”.

The microelectronics industry is and will remain the key to progress in electronics!

Relevance of the ATRM to MEDEA+

The main purpose of this Applications Technology Roadmap (ATRM) is the identification of enabling technologies required for applications that will be needed in 2012. The development of these enabling technologies would then become the subject of future R&D programmes, in particular but not exclusively for MEDEA+ and its successors. For more information on the MEDEA+ programme and its organisation, reference is made to Appendix 7.

To lower the risks run with respect to our future, MEDEA+, amongst others, has to define new and attractive programmes. For this reason the scope of this roadmapping activity was not restricted to the current scope of MEDEA+. On the other hand, this does not automatically imply a scope extension of the current MEDEA+ programme. It is just a first exploration of new possibilities.

Roadmaps

A roadmap is an inventory of possibilities in a chosen field of investigation in a given time frame derived from the collective knowledge and imagination of the brightest drivers of change in that field.

A roadmap consists of a visual and a textual part. The textual part explains what general trends, needs and resulting technology requirements exist in the field of investigation. It usually concludes with a set of conclusions and recommendations to the principal of the roadmapping assignment. The visual part pictures the evolution of the required technologies over time including their relative ordering and dependencies. It also allows to indicate in the same picture a classification of these required technologies according to criteria of choice.

In general, roadmaps help to visualise how needs, solutions/products, technologies, industrial plans and standards will evolve over time in relation to one another. Roadmaps allow these aspects to be considered simultaneously and are therewith offering a coupling at management level of business objectives and technological development choices.

In the technical environment different types of roadmaps are used: product-technology roadmaps, industry innovation roadmaps and technology domain roadmaps (see Appendix 6). The ATRM is a technology domain type of roadmap.

The roadmap covers the time window from today until approximately 2012.

The ATRM activity has been initiated by the Steering Group Applications of MEDEA+ and started in November 2002.

The following people have, in a concerted effort, realised the ATRM:

- A Core-Team of high-level technical managers from MEDEA+ companies (for composition see page 11)
- The MEDEA+ Office for professional help on note taking during meetings and workshop
- A facilitator to manage and guide the roadmapping process
- Many internal and external reviewers and experts to review and comment

Roadmapping methodology and roadmapping process

Usually, roadmaps are created by an extrapolation in time of current R&D activities. This approach has some risks, because it may lead to a complete missing of important new areas. Besides, it is not known in advance if the introduced features will have any market appeal at all. Therefore a new methodology has been developed by the facilitator based on the deliberate identification and definition of expected end-user needs in 2012 as starting point.

The roadmapping methodology starts in its first phase with vision consolidation. Various “vision” documents [2],[3],[4],[5],[6],[7] are studied. From these documents end-user needs in 2012 are to be extracted that express what solutions in different areas of interest for various categories of people would be expected. A major consideration is that only solutions that require electronic circuits for their realisation are taken into account. The list of end-user needs found is to be augmented with needs from still other sources as female relatives, children and businesses co-operating in MEDEA+. Next, these needs are to be consolidated into a vision on 2012 by writing a number of scenarios describing daily live situations in 2012.

In a second phase the step from requirements to technologies is to be taken. Actions are derived from the scenarios. The most relevant actions are to be allocated to the chosen application environments in order to derive the corresponding functions/sub-functions of the solutions required to fulfil the end-user needs. Functions require technologies for their realisation. Therefore, function-technology matrices are to be constructed per application environment by determining which technologies are required to realise each function. A further analysis has to reveal the technological challenges implied by the lists of required technologies per application environment.

In the third phase the actual technology roadmap construction will take place. A roadmap architecture, presenting a structure of user-defined themes, has to be developed for each application environment with the purpose to map all technologies from the function-technology matrix onto. This mapping will result in a set of visuals per application environment showing from an end-user solutions perspective the required technology evolution. Besides producing the visuals accompanying text needs to be written to explain many aspects that can not be reproduced in the visuals. And also conclusions and recommendations are to be presented in written form.

Appendix 6 explains in more detail the chosen roadmapping methodology,

The above described methodology for roadmapping had subsequently to be translated into a roadmapping process taking into account the available resources of manpower capacity and throughput time. The resulting roadmapping process consists therefore of three sequential phases: preparation, construction and last but not least review, publication and follow-up.

In the preparation phase, the methodology, planning and budget were prepared by the facilitator and approved by the MEDEA+ Steering Group Applications. Moreover, they have nominated the Core-Team members.

Next, in the roadmap construction phase a sequence of 9 Core-Team meetings, one workshop, and many interviews with external expert have been organised.

Finally, in the review, publication and follow-up phase a review of the draft roadmap was organised and conclusions and recommendations were refined and finalised. In the follow-up the recommendations have to be executed and the updating of the ATRM, at regular intervals, has to be organised.

On end-user needs

The Core-Team started its work in November 2002 by studying existing vision-related documents and roadmaps [2],[3],[4],[5],[6],[7]. Next, the Core-Team identified end-user needs from these documents. Moreover, additional end-user needs have been defined, based on own experience, imagination, expected needs of the own businesses and various inputs from non-technical people.

In total 114 end-user needs have been collected and have subsequently been clustered in categories, like comfort, education, health, life quality, etc. The results are shown in Appendix 1.

The Core-Team members have consolidated these end-user needs into a vision on 2012 by writing a number (14) of scenarios. All scenarios are presented in Appendix 2.

In Appendix 3 you can find the coverage of end-user needs by the scenarios.

As described above in the second phase, these scenarios were the basis for the remaining roadmapping process. From the scenarios the most relevant actions have been derived and allocated to application environments and subsequently a function-technology matrix per application environment has been constructed (see Appendix 4).

On applications and application environments

The semiconductor industry serves a very broad market, i.e. Telecommunication, Consumer Electronics, Automotive, Electronic Data Processing, Industrial and Military sectors are usually distinguished. Many of the necessary technologies are required in more than one market sector. This overlap poses allocation problems in a roadmap. To avoid this and to come to a sufficiently complete coverage of the major applications that are needed in 2012 according to the vision, a set of application environments was defined that shows a minimal overlap in technologies. It also presented an opportunity to split off the common infrastructure technologies in a separate sub-roadmap. Allocation of technologies to application environments was done on the basis of where the strongest requirements for a technology would originate. Only by introducing such a roadmap structure, a clear and unambiguous insight will be achieved in the relations between applications and technologies.

The four chosen application environments are described below.

The *Within Reach* sub-roadmap describes the application environment with applications literally within reach of the user and including in-body electronic processing and control systems for health maintenance.

The application environment *Within Reach* is characterised by the following usage conditions: autonomous and deeply personalised operation, widely changing environmental conditions in terms of temperature, humidity, noise and light exposure. There is also an exposure to various mechanical strains and exposure to a diversity of networks and protocols.

All these usage conditions lead to a variety of challenges for *Within Reach* applications. Some examples are: mid-to long-term autonomous power supply, low to ultra-low power consumption, autonomous intelligent processing, light-weight and miniaturised components and devices, compatibility.

From the collected user needs, detailed functions and the associated required technologies have been derived. The most important technologies have been grouped in the themes and sub-themes, respectively. The chosen themes are: energy, communication technology, wearable devices, user interaction and personal experience.

The *Stationary* sub-roadmap describes the application environment, which relates to electronic equipment, which is defined for a fixed location and that is basically not moved during operation.

The application environment *Stationary* has been split up in three main themes. The first theme is *Home Environment*. In private homes this includes future intelligent systems for appliances such as refrigerators, washing machines, fixtures like lighting, climate and energy control, personal computers and all types of multimedia equipment. Important topics are: energy management and human-machine interfaces. Various trends have been observed/identified, e.g. a shift from the universal PC to dedicated equipment, installation of several networked home controllers and the home devices will increasingly be networked to allow seamless communication.

The second theme is *Professional Environment*. This theme covers applications like: contactless identification, medical diagnostics, and efficient power electronics, sensors and control units for industrial equipment, imaging and storage. Some trends in this environment are: local energy generation via solar cells or wind generators, new applications based on contactless identification tag, intelligent textiles containing a meshed network of controllers and medical analysis using biochips.

The third theme is *Communication*. This theme covers all kind of physical interfaces of the communication network infrastructure as well as local network equipment, like wireless cellular base station and local-area access point technologies, wired communication, etc. The main trend is broadband access to the network, everywhere and any time. This will lead for instance to broadband cellular networks and WLAN hot spots to allow wireless access on the move, to xDSL evolution that increases the available access bandwidth at home and to harmonisation of network protocols to an all-IPv6 network

The *On the Move* sub-roadmap describes the application environment for somebody “On the move”, with a strong focus on cars. This means that the end user is mobile, e.g. he acts as a driver in a car or as a passenger in a vehicle or he walks. This roadmap only covers the car environment, due to the available expertise in the Core-Team.

The end user in “On the Move” has the following needs: mobility, safety, maintenance and repair, user-friendliness, information, entertainment, comfort and communication. Replacement of mechanical and hydraulic devices by electric and electronic (HW &SW) solutions is the general trend in the car industry. The main drivers for this trend are: time to market, new functions and services, scalability, new regulations, reduction of R&D costs per function, etc.

The application environment *On the Move* has been split up in three main themes. The first theme is *Terminals for infotainment/multimedia*. This includes mobile communication and application support to satisfy user needs for global mobility and personalised multimedia services. Also included are applications that require solutions adapted to car drivers and car passengers. The second theme is *Assistance and convenience system*s for drivers and passengers. This theme deals with all driver assistance and safety features that may assist the car driver and its passengers. The third theme is *Environment-friendly systems*. This theme covers an important and social issue for car manufacturers, producers of automotive systems and semiconductor components. Ultimately, this theme has also consequences for the end user.

The *Common Infrastructure* sub-roadmap covers the communication infrastructure that enables all functions and services offered to the end user that have been described in *On the Move*, *Stationary* and *Within Reach*.

In the vision on 2012, the worldwide network will be a multi-service enabled, quality of service (QoS) enabled, packet-switched network (PSN) characterised by transport, control and service layers well separated from each other and interacting through open interfaces. The PSN will offer to the application and services layer a reliable transport with selectable bandwidth and latency on service demand basis. The PSN will migrate to a converged multi-service network (CMSN) that will largely comply with the "edge-core" approach. This is a functional partitioning or representation, but not a system - or equipment partitioning, as several functions will be merged on different equipment according to the infrastructure equipment architecture strategy.

Based on the defined vision for the *Common Infrastructure,* themes and their relevant enabling applications technologies have been identified. The themes have been defined as the basic technologies required to support the network infrastructure. Within the scope of this application roadmap, focus is on the following four themes: *access infrastructure, intelligent edge, optical backbone* and *security.* These four themes have the largest impact on the semiconductors industry.

Conclusions

With the creation of this Applications Technology Roadmap (ATRM), we have obtained a coherent view on the enabling technologies needed to implement the applications/functions required to fulfil the collected end-user needs in 2012. One should keep in mind that this roadmap is only covering technical issues. Besides, it is a living document and therefore will benefit from future improvement cycles.

We are convinced that the applied method for the creation of this roadmap has proven its value.

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