Ecodesign of electronic devices

UNIT 13: Internet of things - IoT

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Chapter summary:

– Internet of things -IoT
– Development and role of IoT
– Area of IoT

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13.1.Internet of things

Nowadays, the term internet of things is often used. What exactly does this term mean, what does is describe and where does is it originated from? The internet of things is a system of interconnected computer devices, mechanical and digital machines, items, animals or people who are equipped with unique identificators and capability to transfer data through a network without the need for human presence or interaction with the computer. From this explanation, we can conclude that we are talking about devices that are part of internet network and that submit and receive data.

A thing or a person in internet of things can be a person with heart pacemaker with built-in monitor, an animal on a farm with implanted biochip, automobile that has built-in sensors that alarm the driver if the pressure in tires is too low or any other thing that has a dedicated IP address and has the possibility to transfer data through the network. IoT has developed from the convergence of wireless technologies, microelectromechanical systems (MEMS) and the Internet. The convergence has helped eliminate the obstacles between operational technology (OT) and information technology (IT) that enable analysis of data gathered by hardware. IoT model was first presented in 1999 at MIT University (Massachusetts Institute of Technology). The main idea was the following definition. Today computers and the Internet are almost completely dependent on humans. Almost all information and data that are available on the Internet were created by people with typing and pressing buttons. The main problem is that people have limited time, attention and precision. This means that people are not the best at collecting and editing of data. If we had computers that would know everything that they would need to know about certain things, then we could use data gathering and analyses without any human help to significantly reduce waste, losses, and costs. Computers would know when a thing needs to be changed or repaired.

The main limitation of IoT devices is unique identification. This means that each device in the internet network has its own identification number IP. With the use of internet protocol with network layer IPv4 (Internet Protocol version 4), there is unfortunately not enough addresses for all devices. IPv4 uses 32-bit address for addressing devices, meaning the maximum number of devices is around 4 billion. With the implementation of IPv6 that uses 128-bit address, we have significantly increased development and expansion of IoT technology. For an easier understanding, we can say that IPv6 enables so many addresses that each atom on Earth could be given own address and we would still have enough space for 100 Earths. In other words, each thing or device can be given unique IP address. It is expected that with the rise of the number of smart nodes and number of streamed data through the nodes will cause new concerns regarding privacy and data security.

Practical IoT technology applications are nowadays available in many industries, including agriculture, healthcare, energy sector and transport. IoT technology offers the possibility of connecting with electronics engineers and developers of applications that develop efficient IoT devices during collaboration. New types of devices and wide possibilities for applications can connect electrical vehicle, and smart house in which are appliances and different services that provide safety, energy saving, automatization, telecommunication, and entertainment. Both separated systems (automobile and house) can be included in one ecosystem with the common user interface. To be able to create such an ecosystem, we need IoT. The unique ecosystem has to have the capacity to gather and analyze data. Such ecosystem also has to have a certain level of independence, decision-making, and user notification. In future, computer data spaces and communication services will spread and distribute among people, smart things, machines, platforms and surrounding area (for example wireless/wired sensors; M2M devices - Machine to Machine communication, RFID labels, etc.) that will create a very decentralized group of sources that will be interconnected with dynamic networks. Communication language will be based on interoperable protocols that will work in heterogeneous environments and platforms. IoT in this context is a generic expression, and all things can have an important role. Devices will create smart environments where the role of Internet will change significantly. This strong communication tool provides access to information, media, and services through the wired and wireless broadband connections.

Internet of things uses synergy that is made by the convergence of consumer, business, and industrial internet networks, presented in image 1.

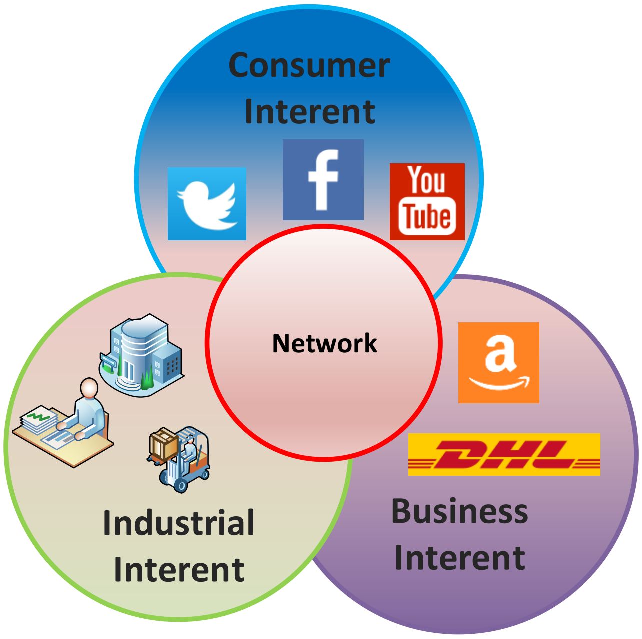

IMAGE 1: CONVERGENCE OF CONSUMER, BUSINESS AND INDUSTRIAL NETWORKS.

The convergence creates an open, global network that connects people, data and things. This convergence uses the cloud to connect intelligent things that sense and transfer a wide amount of data that help create services that would not be possible without such connectivity and analytical intelligence. Use of platform is dependent on new information technologies, such as cloud, cloud computing, IoT devices and mobile phones. The cloud enables global infrastructure creation of new services which consequently encourages development of new content and applications for global users. Cloud computing enables high processing capacity where it is used for different computing resources that are connected to the network. Under computing resources, we mean computers, servers, and other devices that are capable of executing different computing and process operations.

Network IoT is connected to things/devices from all over the world that maintain its identity on the web. Mobile devices enable connection with global infrastructure anytime and anywhere. The result is a globally accessible network of things/devices, users, and consumers that enables the creation of new companies, distribution of content and information and creation of new services. IoT platforms use the power of network connections because these enable the most things at the same time. This way device can be useful for other things and to the users who use their services. The success of IoT platform can be determined by the connection, attraction and data flow.

IoT was enabled by technologies such as; sensor networks, RFID, M2M, mobile internet, integration of semantic data, semantic searching, IPv6, etc... These can be divided into three categories:

- Technologies that allow IoT to gather information..
- Technologies that enable that IoT to process information.
- Technologies for improving safety and privacy.

The first two categories can be seen as functional building blocks that require building of artificial intelligence in the device. These are advanced functions that differentiate IoT devices from regular devices and the Internet. The third category is not functional but a real requirement without which the use of IoT devices would reduce significantly. Development of IoT means that environment, cities, vehicles, clothes, portable devices, and other items are interconnected and have a capability to sense, communicate and gather new information. We can also include other things/devices that are only functional but do not provide information or data flow. A typical example of such device are air conditioning appliances that can be turned on or off via internet with a mobile phone. Development of Internet is based on the transfer of information and social connectivity. With IoT devices, communication via the Internet was extended to things that are surrounding us. IoT is much more than M2M communication, wireless sensor network, 2G, 3G, 4G, 5G, and RFID, etc. These are only technologies that enable IoT.

Image 2 presents a convergence of wireless and wired technologies. In this context, network neutrality is a key element in which no information or data has priority. This means we need to consider the principle of connecting from/to anything, anyone, anywhere, in every moment and use the best possible physical path in any possible way that is available between the sender and the receiver. To be compliant with these principles, internet service providers and governments have to equally treat all data on the Internet without discriminatory sorting depending on the user, content, location, platform, application, equipment, and communication type.

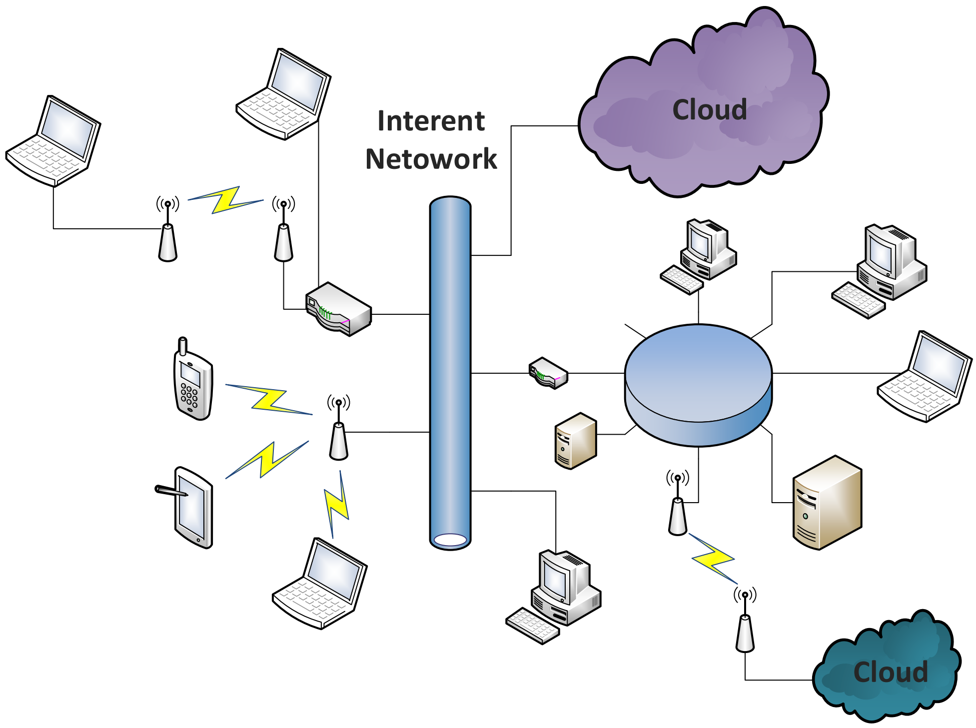

IMAGE 2: CONVERGENCE OF WIRED AND WIRELESS TECHNOLOGIES.

Development of IoT devices includes knowledge from the development of classic electronic devices. The IoT concept is closely related to ecological factors. When ecodesigning IoT devices, the main criteria is providing the highest possible device autonomy. This means that device is available for longer and does not need additional charging. IoT devices that are constantly plugged into the network also need to be built in a way that they consume the least possible amount of energy when operating. Designing of devices has to be simple and efficient. With the growth of IoT device, the questions on energy consumption and other resources arise. Will the use of new technology enable reasonable consumption of natural resources or will the new technology even increase it?

13.2. Areas of the Internet of things

It is impossible to predict all potential applications of IoT technology, especially considering the development of new technologies and different needs of potential users. In the following chapters, we will present some of the most important areas. These applications present important research, development, as well as economic challenges. IoT areas work on needs of society, progress, and new technologies. Amongst new technologies are also nanoelectronics and cyber systems. The latter are still working on technical, institutional and economic issues. The list of areas is limited to applications that IERC (European Research Cluster on the Internet of Things) has chosen for priority tasks for the next year.

13.2.1. Smart cities

Shortly, the development of city corridors and full cities connected in a uniform integrated city network is expected. The current trend predicts that more than 60% of world population will live in urban cities until year 2025. The urbanization as a trend will have a huge impact on future society and mobility. The rapid expansion of city centers due to the rapid increase of residents and development of infrastructure will force smaller cities to expand outside and from the near-by cities form megacities with more than 10 million residents. Until 2024, 30 megacities are expected globally, of which 55% will be developing in economies of India, China, Russia and Latin America. This will lead to the development of smart cities with eight fundamental strategies, which are: smart economy, smart building, smart mobility, smart energy, smart information-communication technology, smart planning, smart citizenship and smart management. Until 2028 there will be approximately 35 smart cities in the world.

The role of city authorities is crucial for IoT implementation. Management of daily city activities and formation of strategies for city development will encourage the use of IoT. This is the reason why cities and their services are an almost ideal platform for research of IoT technologies. We also need to consider the requirements of cities and transfer of ideas to the final solution that is enabled by IoT technology. In Europe, the largest smart city initiatives that are completely oriented towards IoT are implemented in project FP7 Smart Santander. The purpose of this project is the establishment of infrastructure for internet access that includes thousands of IoT devices inside some large cities, such as Santander, Guildford, Luebeck, and Beograd. This will encourage direct development, evaluation of services and execution of different research experiments, which will enable formation of the smart city environment.

The suggested smart city vision is presented in a horizontal form in which are also many vertical scenarios that would enable the concept of smart life, seen in image 3 [2].

IMAGE 3: PRESENTATION OF A DAY IN SMART CITY.

The image presents several common actions that are done in a smart day, wherein each case also has a label which area is used. Such horizontal scenario means the use of heterogeneous basic communication technologies and provides the user with interaction with different advanced IoT services.

In this context, there are several important development challenges for IoT applications in smart cities:

- Overcoming of traditional city organizations that are outwards relatively closed and only work on own problems. Although this is not a technological problem, it is still one of the main obstacles.
- Production of algorithms and processes for data flow and measurement that are gathered by different sensors in different applications. Gathered data needs to be suitable for use and exchange between different city services.
- Develop cost-effective mechanisms of use and maintenance of these devices, including disposal or recycling.
- Providing reliable measurements and use of data from many sensors. Effective calibrating of a large number of units, arranged on different locations, from lamps to workstations need to be provided.
- Low-energy protocols and algorithms.
- Algorithms for analysis and processing of data gathered in the city.
- High integration of IoT technology.

13.2.2. Smart Grid

The general public is increasingly aware of changing politics on energy supply, energy consumption, and infrastructure. For multiple reasons, our future energy supply should not be based on fossil fuels anymore. Nuclear energy is also not the energy of the future, which was confirmed by many studies. Due to this, our future energy supply should be based particularly on different renewable sources. Our attitude and behavior towards energy consumption also have to change. Because of its “inconsistent nature”, this way of supply requires intelligent and flexible electrical network that can respond to different fluctuations of transferred power with control over electrical sources and reconfiguration of the network. Those network characteristics are based on intelligent network devices and elements of network infrastructure that are mainly on IoT concepts. In the ideal case, this means constant control over current energy consumption on the individual customer of a certain device. Information on current energy consumption that the customer has insight into is the first step to smart energy consumption.

For new energy, networks will be typical a large number of distributed small, and medium sited energy source and power plants that can be combined in large virtual power plants. In case of outage or accident in energy network, some areas can be separated from the main network, and local internal source can still supply this area. Local energy sources can be small power plants and photovoltaic on building roofs. Image 4 presents modern smart electrical network that consists of different sources.

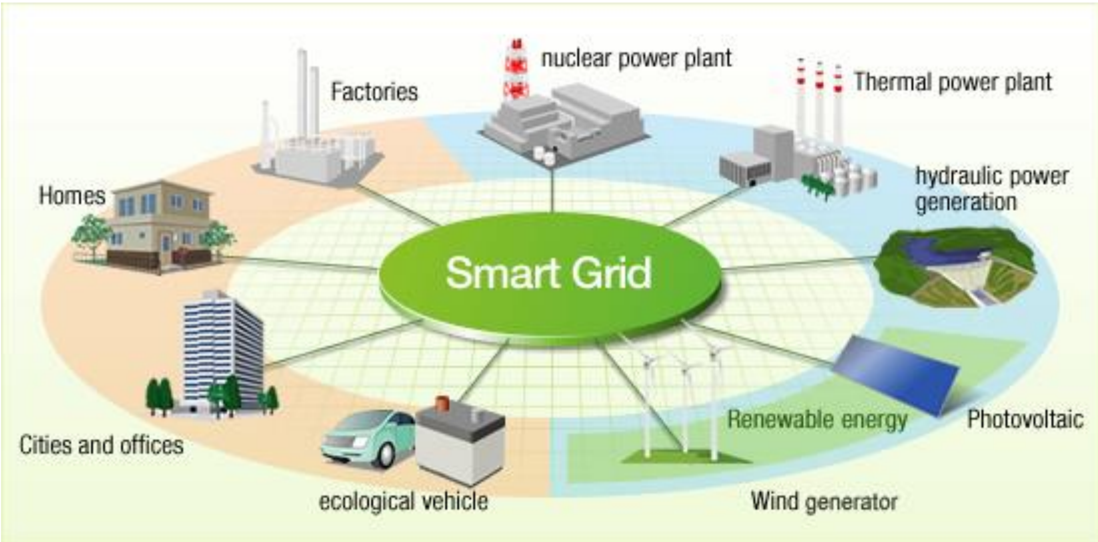

IMAGE 4: STRUCTURE OF SMART ENERGY NETWORK.

A great challenge for implementation of new technologies such as cyber-physical systems are planning and use of infrastructure in energy systems. Those systems have to provide distribution of electrical energy without interference, is still adjustable to enable heterogeneous power supply and is protected from random or deliberate manipulations. The main engineering problem is the integration of existing technology and technology of cyber-physical system on the existing electrical network and other network elements. The increased system complexity presents new technical challenges that need to be foreseen. The upgraded system works in a way that was first not foreseen and uses the existing infrastructure. The biggest concern presents safety because the devices connected to the network are subject to different remote attacks and misuses. IoT applications that include heterogenous cyber system are also dealing with these problems.

Evolving smart network in image 4 is supposed to implement the new concept of a network that can effectively direct energy transfer from source to the user. Efficient transfer means that we have the lowest possible losses at energy transfer. Smart networks would be capable of directing energy from the nearest energy source to the user. The network would need to meet quality requirements and standards that are defined for energy distribution. It is expected that smart network would work as "internet" in which energy packages will be managed similarly as data packages – through routers and nodes that can automatically decide for the optimal path of the packages to the final destination.

In the aspect, the concept "Internet of Energy" IoE is set as network infrastructure that is based on standard communication transmitters, nodes, and protocols. Those have to allow a balance between local and global energy production and storage capacities. This will lead to high level of awareness and inclusion of consumers to the energy system. This way, IoE provides an innovative concept of distribution, energy storage, network control, and communication.

Image 5 present IoE network structure.

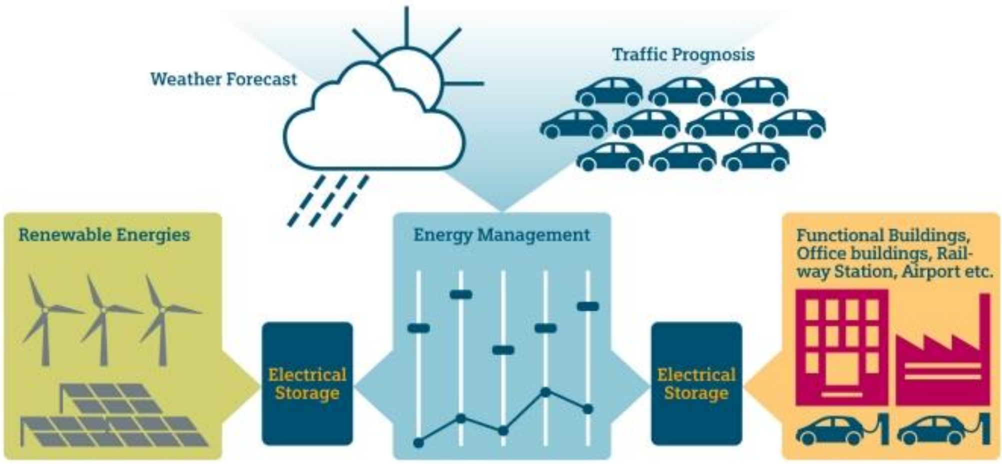

IMAGE 5: IOE NETWORK STRUCTURE.

The network will enable transfer of energy units when and where it will be needed. Energy consumption control will be done at all levels, from local to national to international level.

Energy saving that will be based on improved user awareness on current energy consumption is the second column of future concepts on energy management. Smart counters can provide the user with information on current energy use which enables identification and removal of devices with the highest usage and this way optimize energy consumption. In a smart network scenario, the energy consumption will be determined by variable price. The price will be based on current demands obtained from smart counters, available energy quantities, and production of renewable energy. On the virtual energy market, the agent with software can negotiate energy prices and give energy orders to energy companies. These companies need to consider environmental information, such as weather forecast, local and season conditions.

Long-term, electromobility will become another important element of smart electro-energetic networks. An example of electrical mobility ecosystem is presented in image 6. Electrical vehicles (EV) can only work as network load or as mobile energy storage. The vehicles will be connected to IoT devices via a smart network. When managing electrical vehicles through IoT devices with the smart network, we will need to consider also energy demand and offers in residential areas and near main roads based on traffic and weather forecast. EV will work as consumers or sources of energy. This is based on battery charging, current energy supply in batteries, consumption range, and energy price. This simply means that non-moving car for which idle time is predicted will deliver energy from the battery to the network for a certain amount of time. Before use, it will charge depending on the distance we want to travel and current energy price. This is the center point from which we can create following scenarios of telematic internet connections with smart network and IoT.

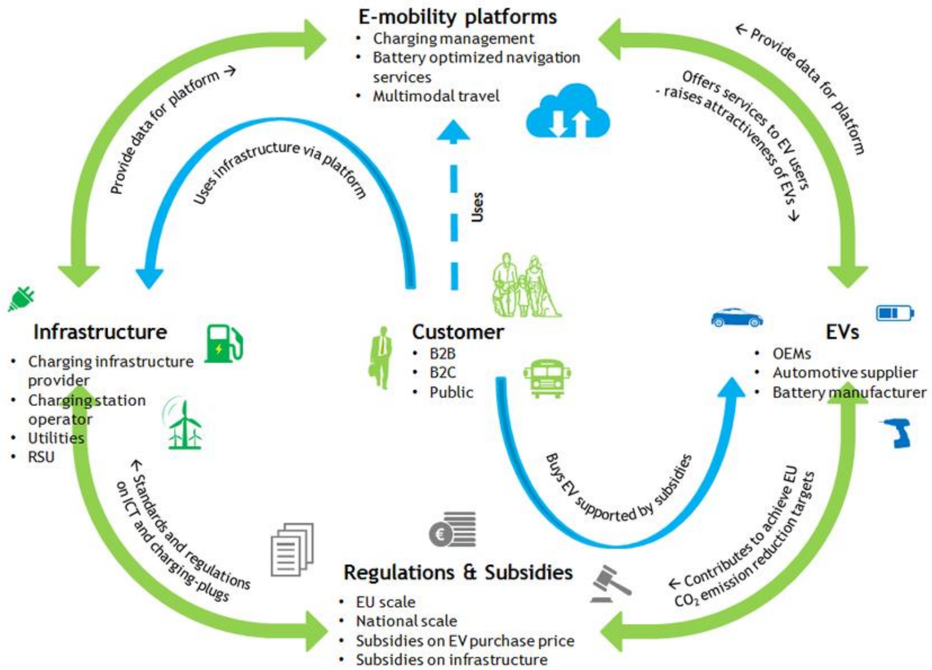

IMAGE 6: ECOSYSTEM OF ELECTRICAL MOBILITY [2].

This scenario is based on the existence of IoT networking, a large number of intelligent sensors and actuators which can communicate safely and reliable. Energy consumption is crucial for this. To ease interaction between products by different manufacturers, technology would need to be based on standardized communication protocols. When dealing with critical part of the public infrastructure, data safety is the most important. To satisfy incredibly high requirements regarding energy network reliability, the components and their interaction need to have the highest reliability. There will also be needs for new organization structure of sensor networks and only this way we will effectively confront drawbacks of classic hierarchy control concepts. Depending on the connectivity of IoT devices that are based on cloud structures can benefit analysis of energy consumption and hardware efficiency. For management of large quantities of raw data that are gathered from multiple data sources, will be needed complex and adjustable filtering and processing algorithms. Systemic and data models have to support the design of adaptive systems that provide reliable and safe operating in real time.

13.2.3. Smart transport and mobility

Connecting to all vehicles types, not only electrical ones with the internet will cause many new possibilities and applications that can make transport easier and more functional. In this context, we are talking about the Internet of Vehicles (IoV) that is connected to the concept of IoE, which presents future trend and bases of smart mobility. Simultaneous establishment of new mobile ecosystems that are based on safety, comfort of mobile services and transport applications, will provide high comfort of transactions and services.

Development of autonomous vehicles presents a great challenge for engineers, as well as for the users. When designing autonomous vehicles, we need to consider the human factor. There is also needed trust in technology user and its safety. There is a limited understanding how cyber traffic controllers will influence driver's behavior. Integration of autonomous vehicles into the existing traffic is done gradually, meaning that for a while we will use traffic that will consist of autonomous and non-autonomous vehicles. Here it is difficult to consider the stochastic behavior of the human driver in mixed traffic. Integration of autonomous driving requires high-security measures that are not only physical but also logistical. Meanwhile, safety traffic regulation is not changing. In this case, cyber-physical systems become more complicated because the interaction between components increases. Safety communication protocols will still have the original meaning. All these elements have utmost importance for IoT ecosystem that is and will be developed based on new and upcoming technologies. An example of an autonomous energetic ecosystem is presented in image 7.

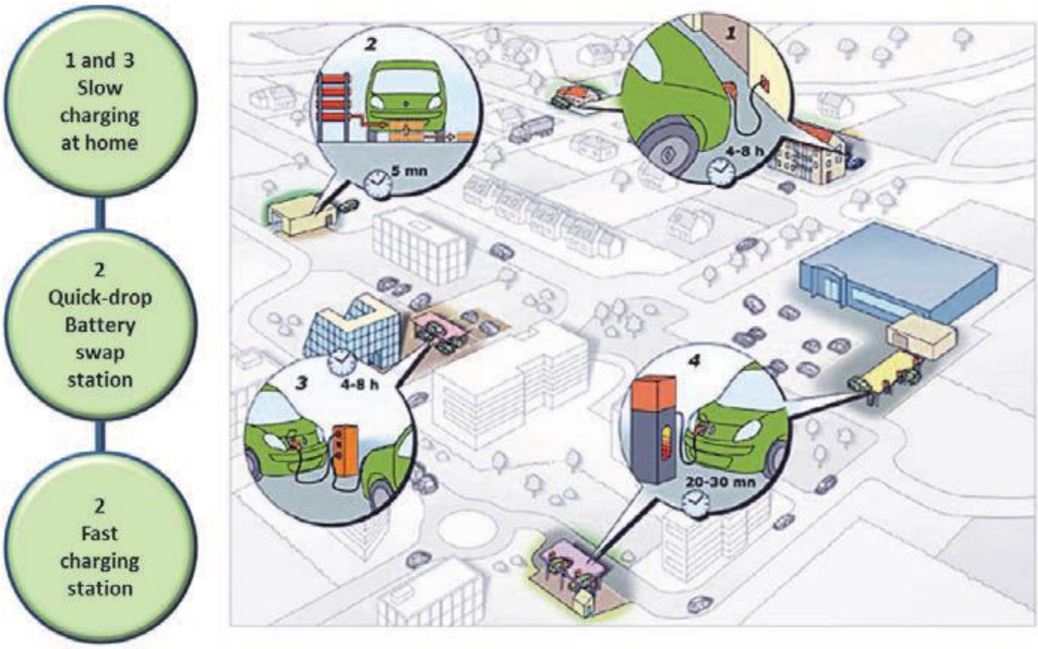

IMAGE 7: AUTONOMOUS ENERGETIC ECOSYSTEM (SOURCE: RENAULT NISSAN).

When we are talking about IoT in the context of automotive telematics, we can present the following scenarios:

- The standards regarding power electronics supply voltage are needed, but it is also needed to determine if all charging processes are controlled by a system inside the vehicle or in the filling station.
- It is needed to develop systems for two-sided operations: charging and emptying – energy storage. It is needed to determine a system of flexible energy billing if all electric vehicles are used as energy storage.
- IoT can be a component of vehicles that controls and manages the vehicle. Already today, service center monitors some parameters in the vehicle and inform the user of vehicle condition and possible needed service. The service centers also take care of timely spare parts delivery and organizing work.
- IoT enables management and control over the traffic. Vehicles and routes would be organized in a way that we could avoid traffic jams and optimize fuel consumption. This could be done with the suitable infrastructure of smart city. Mutual communication between vehicles and infrastructure allow new possibilities for optimization, reducing and redirecting of traffic in traffic jams or accidents.
- IoT enables new transport scenarios – modal traffic. In this case, the automobile manufacturers would be mobility providers and not only vehicle manufacturers. They would offer the user an optimal solution for transport from point A to point B based on available and suitable means of

transport. Based on current transport infrastructure, the ideal solution is car sharing and the combination of railway and road systems. To provide flawless use and timely availability of all means of transport, it is needed to check availability and provide online registration. This approach is suitable in relation to previously mentioned smart city system for traffic control.

13.2.4. Smart building

With spreading of WiFi networks in business buildings and residential buildings, has appeared the possibility of smart building management. All devices in the building are connected to the internet network and are part of internet network inside the building. There is no need to emphasize that IoT technology has the main role. The benefit of this type of smart building is that there is no need for own house network because for communication is used IP protocol. All devices in the network have to have wired or wireless connection to the internet network. This also enables remote control over the building. This means that the user can turn on the heating, turn off lights, etc. even if he is not present in the building. External access to the building is enabled through different services. A smart building can be accessed through portable devices, such as phones, tablets, laptops or online applications that are not dependent on portable platform, image 8. IoT devices and wireless sensor network have a crucial role in achieving this. Also, safety is crucial in other applications. Many companies have developed own systems of sensor networks for smart buildings which are later connected to internet networks and have remote access and control. With this, we want to increase safety and reliability of system operating. Smart buildings enable a higher level of living and higher comfort at maximum energy efficiency.

IoT devices that collect information on building with sensors together with cloud technology enable deeper analysis and optimal management of buildings with maximum efficiency.

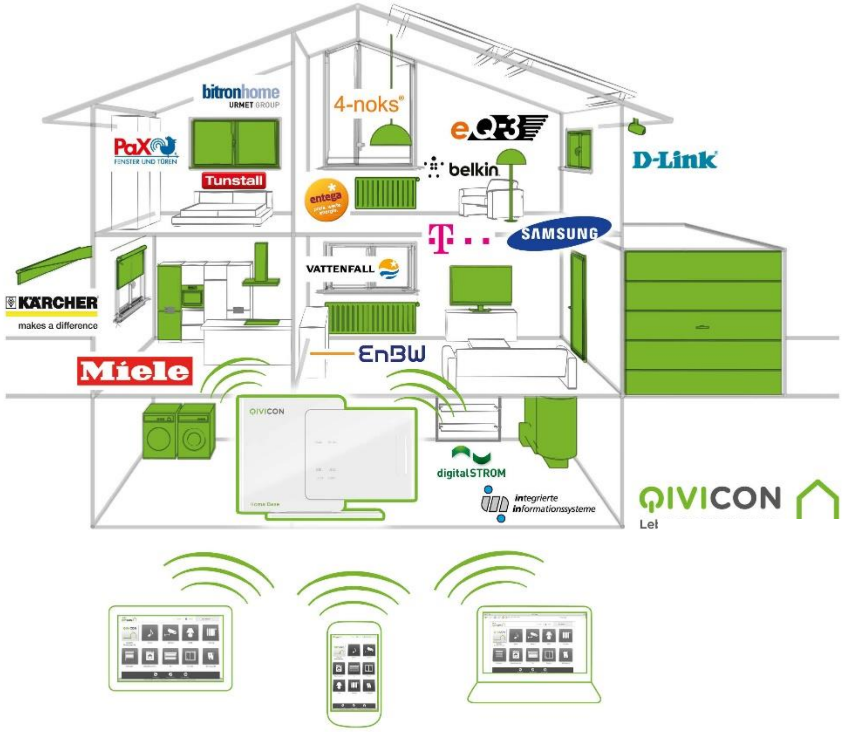

IMAGE 8: SMART BUILDING CONCEPT.

The main problems in integrating smart building integration are most commonly at ownership of multi-apartment houses and payment of initial costs. Another problem is lack of cooperation with the construction industry and slow penetration and accepting of new technologies. Nevertheless, the concept of smart buildings is expanding in the new buildings and slightly less often in adapted and renovated buildings.

13.2.5. Smart manufactory

The role of IoT technology is becoming more visible in well-organized production plants. IoT enables access to devices and machines that together build digitalized production systems. This way, IoT will undertake a series of applications and services that are important for successful production functioning. This could first include connecting of plants into smart networks, sharing of production sectors which would significantly increase agility and flexibility of production system. In this sense, the production system would present one IoT unit where we could determine new ecosystem for smarter and more efficient production.

The first evolution step to smart plant in common use could be done in a way that the access to the plant would be given to external stakeholders. Those would access production processes and the plant via the internet. Stakeholders would include suppliers, production, logistics, and maintenance. Such IoT architecture challenges the hierarchical and closed plants that usually have a pyramid system where external stakeholders have lower influence. The room for innovation and new applications could be increased to the same extent as for embedded systems that have steeply risen since the implementation of smartphones.

One of the key factors for smart and agile production is a way how to manage and access physical world. In the physical world, we need to access sensors, actuators and production units and be managed similarly as this is enabled by IoT technology. All IoT devices provide their services in a well-structured way and can be managed with multiple applications that can run in parallel.

13.2.6. Health

The current market of devices for health control is very fragmented and unstructured. We know many different electronic devices for monitoring and measurements of vital bodily functions. For all devices, it is common that their usefulness is different depending on their intended use. Devices are built on different platforms. Although individual products are intended for reaching price objectives, the long-term goal is directed towards reaching of lowest technological costs. This can be reached with the use of coordinated approaches and platforms.

Applications of health monitoring can be divided into the following groups:

- Applications that collect data from sensors.
- Applications that have to support user interfaces.
- Applications that need network connection for access to the services.
- Applications that have to meet the following requirements, such as: low power, robustness, durability, precision, and reliability.

IoT application encourages the development of following platform - AAL (ambient assisted living) systems. ALL offers services in the field of daily activity help, health monitoring, safety improvement and access to health and emergency rescue services. The main goal is improving quality of life for people who need constant monitoring or accompaniment. When monitoring daily activities and bodily functions, we can avoid unwanted complications, consequential costs of treatment and provide medical care on time.

Convergence of biosensors, communication technology, and engineerings, changes healthcare into a new type of information industry. In this context, the advancement that exceeds IoT technology for healthcare is anticipated in the following steps:

- Standardization of interfaces and sensors with the open platform for creating a wide and open market for biochemical innovators.
- Providing a high level of automatization when accepting and processing information.
- Data in real time through the network have to be accessible anywhere on the internet and have to be supported with suitable software.
- Reuse and uniform structure of device components for an easier transition to a cheaper device for home use. More expensive professional devices would be stationed in hospitals and nursing facilities.
- Data have to be portable between authorized devices that are used in clinical care at home, clinic or hospitals.

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