10

The Next Mobile Communication Steps into New Application Areas

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10.1 Introduction and Mobile Pioneer Phase

The digital mobile communication started 1992 with first GSM network deployments in Europe, called 2nd Generation. Meanwhile we are discussing 5th Generation networks planned to start first deployments in 2020. This chapter describes the mobile evolution and its highlights. It will consider 5G technologies focus on new application areas which are not yet covered by mobile communication systems. As an example for new application areas it will describe a decentralized energy storage system and its mobile communication requirements to make renewable energy supply viable. The chapter ends with Conclusions and outlook.

Mobile communication is older than many today's users would expect. During the first period, called the pioneer phase from 1921 to 1945, mobile radio technology was still quite premature and dominated by the mechanical problem designing a radio system that could survive the bumps and bounces of a moving vehicle. These initial radio systems were based on amplitude modulation radio and no commercial services were established. The invention of frequency modulation was an important determinant and the World War II brought tremendous improvements in designs. This first pioneer phase is marked by three topics [1]:

- mainly used by military and paramilitary groups,
- building a radio transmitter capable of operating within the size and power constrains of a moving car and
- radio transmission based on frequency modulation.

The next phase of development of mobile communication systems is the expansion of mobile telephone services into commercial use. The technical improvements were oriented towards two goals:

- reduction of transmission bandwidths and
- implementation of automatic trunking.

The next step of the early mobile communication systems was

- cellular structuring.

This innovation represented a totally new approach of deploying radio networks. It was the idea to extend the capacity to an unlimited system, breaking through the limits that had restricted the growth of the mobile communication.

10.2 Analog Mobile Communication Systems

After World War II a lot of mobile communication systems based on analog technology were deployed in different countries. This was the start of the commercial phase, but still a niche market. These networks had following attributes:

- analog air channel,
- narrow band communication,
- voice centric services,
- only national roaming,
- FDD based,
- less subscriptions compared with today,
- expensive tariffs,
- used in cars mainly and

were called 1st Generation of mobile communication systems. Most common 1st Generation systems are AMPS, TACS, NMT and C-net.

10.3 Digital Mobile Communication Systems

A totally change in the mobile communication began with the development of first digital systems in the eighties of the last century with first deployments 1992. It started from a niche market with less subscriptions and high tariffs to a mass market with very high penetration and flat rates and remarkable changes of our daily human behaviour. It is in the meanwhile unimaginable to live without a mobile terminal. The most successful system of this 2nd Generation of mobile networks was GSM, which was planned as a mobile communication system for Europe only and conquered nearly the whole world in less than 10 years. In 2002, when the 3rd Generation started, 62% of the worldwide subscriptions were based on GSM (Figure 10.1). The reasons for this success were:

- fully digital transmission,
- enhanced frequency economy,
- privacy,
- improved hand-held viability,
- flexible configuration of networks and services,
- international compatibility,
- enhanced services.
- based on field-proven digital switch technology,
- open Interfaces,
- multi-vendor architecture,
- competitive operator concept and
- early system availability.

But nevertheless the killer application still was mobile voice service. 2nd Generation standards were narrow band systems with voice centric services and the first real data services started with the introduction of GPRS, what led

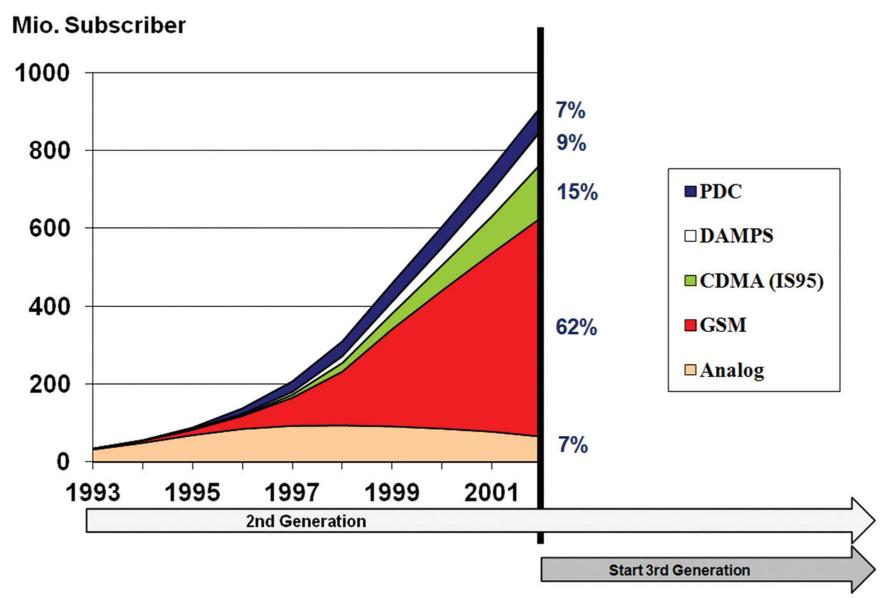

Figure 10.1 Worldwide subscribers from 1993 to 2002 of different 2nd Generation standards.

to an extended architecture. Another milestone was the introduction of the IN-architecture with prepaid service. The next step into broadband was the development of EDGE architecture with the success to become member of the IMT 2000 family. EDGE gives GSM/GPRS-Market new significant boost and business potential, EDGE and 3G WCDMA are complementary not competing and EDGE is the smooth migration path to 3G-services in existing spectrum. Although EDGE requires no hardware or software changes to be made in GSM core network, base stations must be modified. EDGE compatible transceiver units must be installed and the base station subsystem needs to be upgraded to support EDGE. New mobile terminal hardware and software is also required to decode/encode the new modulation and coding schemes and carry the higher user data rates to implement new services.

The International Telecommunications Union (ITU) launched a new framework of standards under the generic name of IMT-2000 to present the culmination of ten years study and design work to identify the 3rd Generation standards. The following key factors were established [2, 3]:

- high speed access, supporting broadband services such as fast Internet access and multimedia applications,
- flexibility and support of new kinds of services and
- offer of an effective evolutionary path for 2nd Generation existing wireless networks.

The market expectations were focused on more advanced services than voice and low data services considering merging three worlds which have operated so far independently the computer and data activities, the telecommunication and the audio and video content world. Multimedia applications use several services in parallel such as voice, audio, video data, e-mail, etc. and have to be supported by the radio interface and the core network. The main focus on this merged field of activities is to generate new business opportunities and multimedia mobile communication (Figure 10.2). UMTS was the first radio network with FDD and TDD radio access technologies. For FDD was chosen WCDMA as multiplex method and access technology for TDD was TD-CDMA [2]. TD-CDMA was improved by the Chinese to TDSCDMA and deployed in China. UMTS networks were ATM/IP based with full roaming through different networks and broadband services like internet access and multimedia services. UMTS was standardized by 3GPP.

To improve broadband access to get DSL-like broadband speeds HSPA was standardized in Release 5 (Downlink) and Release 6 (Uplink) of 3GPP. Mobile broadband moved a step faster with HSDPA delivering up to 14 Mbps in the

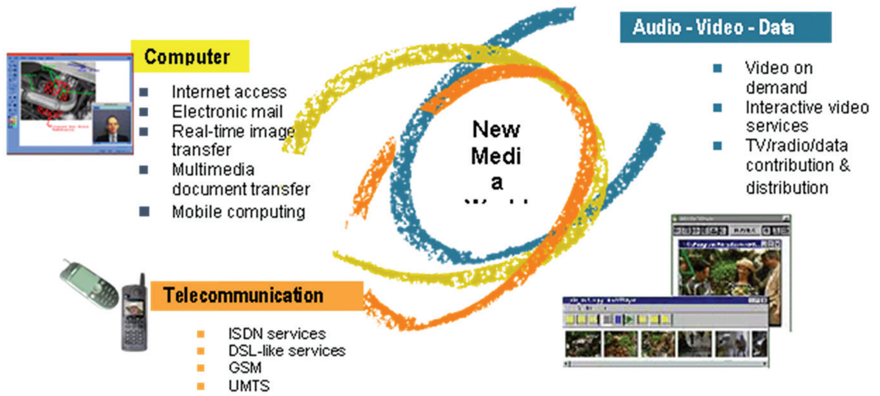

Figure 10.2 Converging three worlds generates new business opportunities (Picture Siemens).

downlink and HSUPA returning 5.8 Mbps in the uplink. HSPA improvements in UMTS spectrum efficiency were achieved through new modulation (16 QAM) formats, reduced radio frame lengths and new functionalities within radio networks (including retransmissions between Node B and the Radio Network Controller). Consequently, throughput is increased and latency is reduced (down to 100 ms and 50 ms for HSDPA and HSUPA respectively). By the end of 2007, there were 166 commercial HSDPA networks in 75 countries in operation and further 38 networks committed to deployment. The first commercial launch of HSUPA was in early 2007 and 24 networks had launched by the end of the year.

CDMA 2000, mainly developed in US and successor of the 2G standard IS 95, became member of the IMT-2000 family too. It is a hybrid 2.5G/3G standard of mobile communication that use CDMA, a multiple access scheme for digital radio, to send voice, data, and signaling data between mobile phones and cell sites. CDMA 2000 is considered a 2.5G protocol in 1xRTT and a 3G protocol in EVDO.

CDMA is a mobile digital radio technology that transmits streams of bits and whose channels are divided using pseudo noise sequences. CDMA permits many radios to share the same frequency channel. Unlike TDMA, a different technique used in GSM and DAMPS, all radios can be active all the time, because network capacity does not directly limit the number of active radios. Since larger numbers of phones can be served by smaller numbers of cell sites, CDMA-based standards have a significant economic advantage over TDMA-based standards, or the oldest cellular standards that used frequency division multiple access (Figure 10.3).

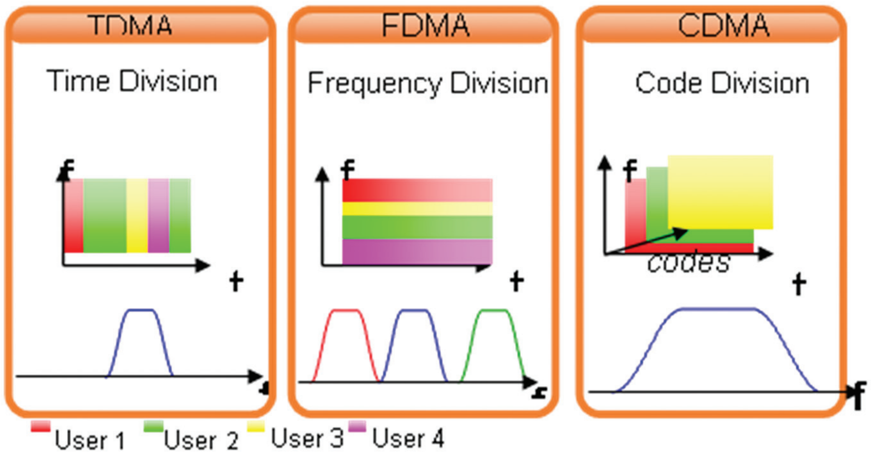

Figure 10.3 Major multiple access methods used in 2nd and 3rd mobile radio standards (Picture NSN).

CDMA 2000 remains compatible with the 2nd Generation CDMA telephony methods IS 95. The CDMA 2000 standards CDMA2000 1xRTT, CDMA2000 EV-DO, and CDMA 2000 EV-DV are approved radio interfaces for the ITU's IMT-2000 standard. CDMA 2000 is an incompatible competitor of the other major 3G standard UMTS. It is defined to operate at 400 MHz, 800 MHz, 900 MHz, 1700 MHz, 1800 MHz, 1900 MHz, and 2100 MHz. CDMA2000 was standardized by 3GPP2. IMT 2000 allocated worldwide news spectrums for 3G for FDD and TDD applications, except North America (Figure 10.4).

After deployment of HSPA and spreading of smartphones the mobile data traffic in the 3G networks increased extremely. Attractive HSDPA flat-rate mobile-broadband services offered to drive strong increase in traffic volumes. As traffic still grows faster than revenue, networks had to become more efficient. This required low cost per bit technologies and was one of the main arguments to push 4G (Figure 10.5).

LTE/SAE (Long-Term Evolution/System Architecture Evolution) is a standard for wireless cellular communication of high-speed data for mobile terminals. It is evolutionary based on the GSM/EDGE and UMTS/HSPA network technologies, increases the capacity and speed using a different radio interface together with core network improvements and decreasing the network costs /4,5/. The standard is defined by the 3GPP and is specified in its release 8 document series, with minor enhancements described in release 9.

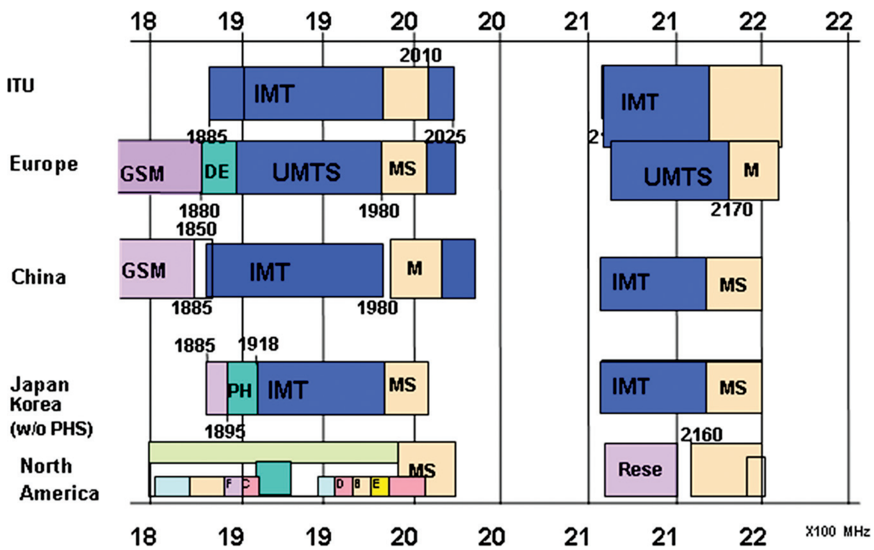

Figure 10.4 IMT 2000 worldwide frequency plans (Picture Siemens).

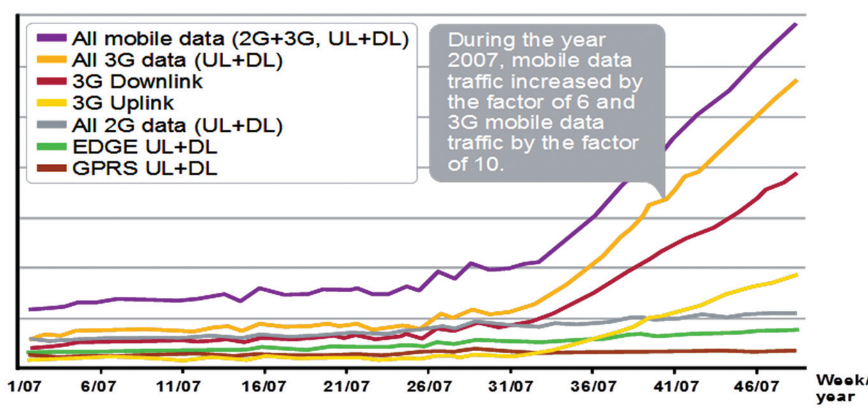

Figure 10.5 Mobile data traffic growth during the year 2007 (Picture NSN).

LTE is the natural upgrade path for carriers with both GSM/UMTS and CDMA 2000 networks. Only multi-band phones will be able to use LTE in all countries where it is supported. The key benefits for operators and users are:

- only one network element in radio and core each (Figure 10.6),
- enhancement of packet switched technology,
- high data rates, low latency, packet optimised flat IP system,
- comprehensive security,

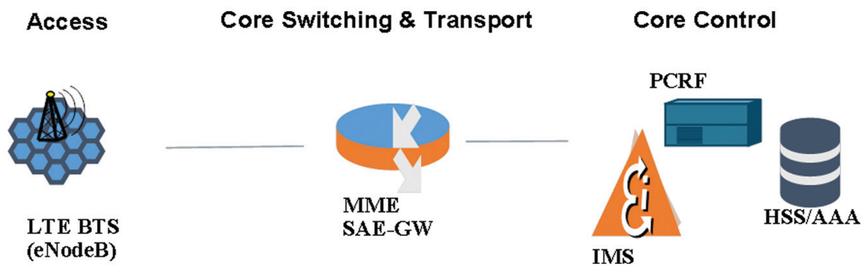

Figure 10.6 LTE/SAE system architecture (Picture NSN).

- mobility concept with tight Integration for 3GPP access,
- streamlined SAE bearer model with network centric QoS handling and
- on/offline and flow based charging.

Although marketed as a 4G wireless service, LTE (as specified in the 3GPP release 8 and 9 document series) does not satisfy the technical requirements the 3GPP consortium has adopted for its new LTE Advanced standard. The requirements were originally set forth by the ITU-R organization in its IMT Advanced specification. However, due to marketing pressures and significant advancements that WiMAX, Evolved High Speed Packet Access and LTE bring to the original 3G technologies, ITU later decided that LTE together with the aforementioned technologies can be called 4G technologies [4]. The LTE Advanced standard formally satisfies the ITU-R requirements to be considered IMT-Advanced [5–7].

- MME: Mobility Management Entity
- PCRF: Policy and Charging Control Function
- SAE-GW: System Architecture Evolution Gateway
- IMS: IP Multimedia Subsystem
- HSS: Home Subscriber Server
- AAA: Authentication, Authorization and Accounting

LTE radio interface use different methods in downlink and uplink. For downlink OFDMA with

- improved spectral efficiency,
- reduced interference,
- very well suited for MIMO and

for uplink Single-Carrier-FDMA with

- power efficient uplink increasing battery lifetime,
- improved cell edge performance by low peak to average ratio and
- reduced terminal complexity.

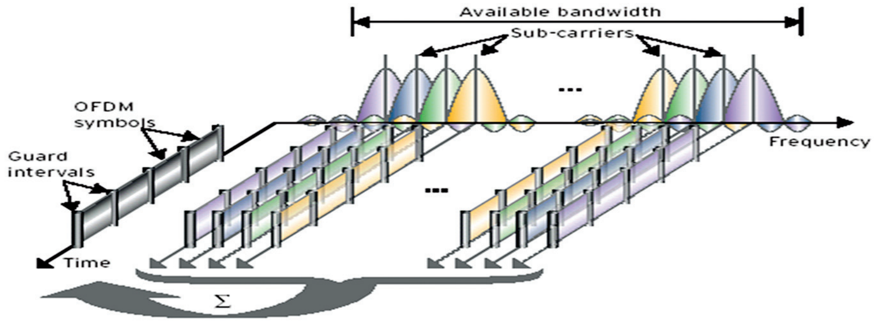

Figure 10.7 LTE radio principles (Picture NSN).

Further topics:

- enabling peak cell data rates of 173 Mbps downlink and 58 Mbps in uplink at 20 MHz bandwidth, FDD, 2 TX, 2 RX, DL MIMO, PHY layer gross bit rate
- scalable bandwidth: 1.4/3/5/10/15/20 MHz also allows deployment
- in lower frequency bands (rural coverage, refarming)
- short latency: 10–20 ms roundtrip ping delay (server near RAN)
- FDD and TDD timing.

Figure 10.7 illustrates the LTE radio principles. Core technology is based on the Mobility Management Entity with C-Plane part of a GW, session and mobility management, idle mode mobility management, paging and AAA proxy. The serving gateway contains user plane anchor for mobility between the 2G/3G access systems and the LTE access system and lawful interception. The packet data network gateway implies the gateway towards internet/intranets, user plane anchor for mobility between 3GPP and non-3GPP access systems like home agent, charging support, policy and charging enforcement, packet filtering and lawful interception (Figure 10.8).

The roadmap of the digital mobile network evolution towards 5th Generation, starting with first network operation based on GSM 1992 until today shows Figure 10.9.

10.4 5G Requirements and Technologies

Although 4G Technology is still in rollout a lot of research- and industry activities have started already. With 5G a new phase of mobile communication will start and the focus is on the billions of terminals available in the internet

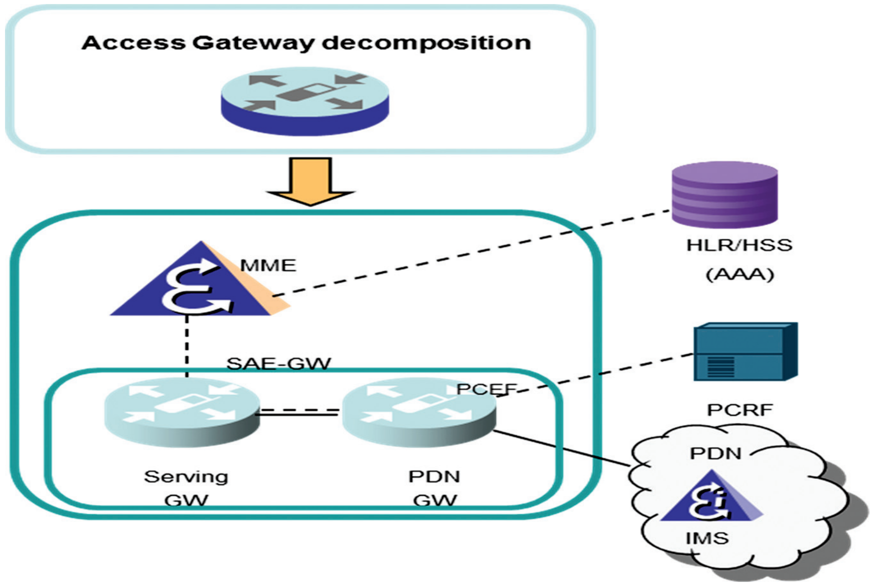

Figure 10.8 Core network principles (Picture NSN).

of things. We can, therefore, deduce that data traffic will continue to increase dramatically over time. It is estimated 1000 times by 2020. Connected devices will increase over time by 10–100 until 2020. New device types like probes, sensors, meters, machines, control computers etc. will significantly contribute to that increase. New sectors will bring new priorities, like future cars with car-to-car communication and real time navigation, Industry 4.0 with plant of the future, Energy with decentralized energy production and energy storage and real estate with metering, consumption control etc. Broadband communications will stimulatethe economy by contributing significantly to GDP and creating employment. From a user's point of view 5G networks should enable the perception of infinite capacity, tactile internet and augmented reality. Compared to existing networks, 5G networks will need to be more available, more dependable and more reliable and offer increased speed, increased throughput, decreased latency, improved deviceautonomy and must be offered at low cost. "5G is an end-to-end ecosystem to enable a fully mobile and connected society. It empowers value creation towards customers and partners, through existing and emerging use cases, delivered with consistent experience, and enabled by sustainable business models" is the NGMN 5G vision [10].

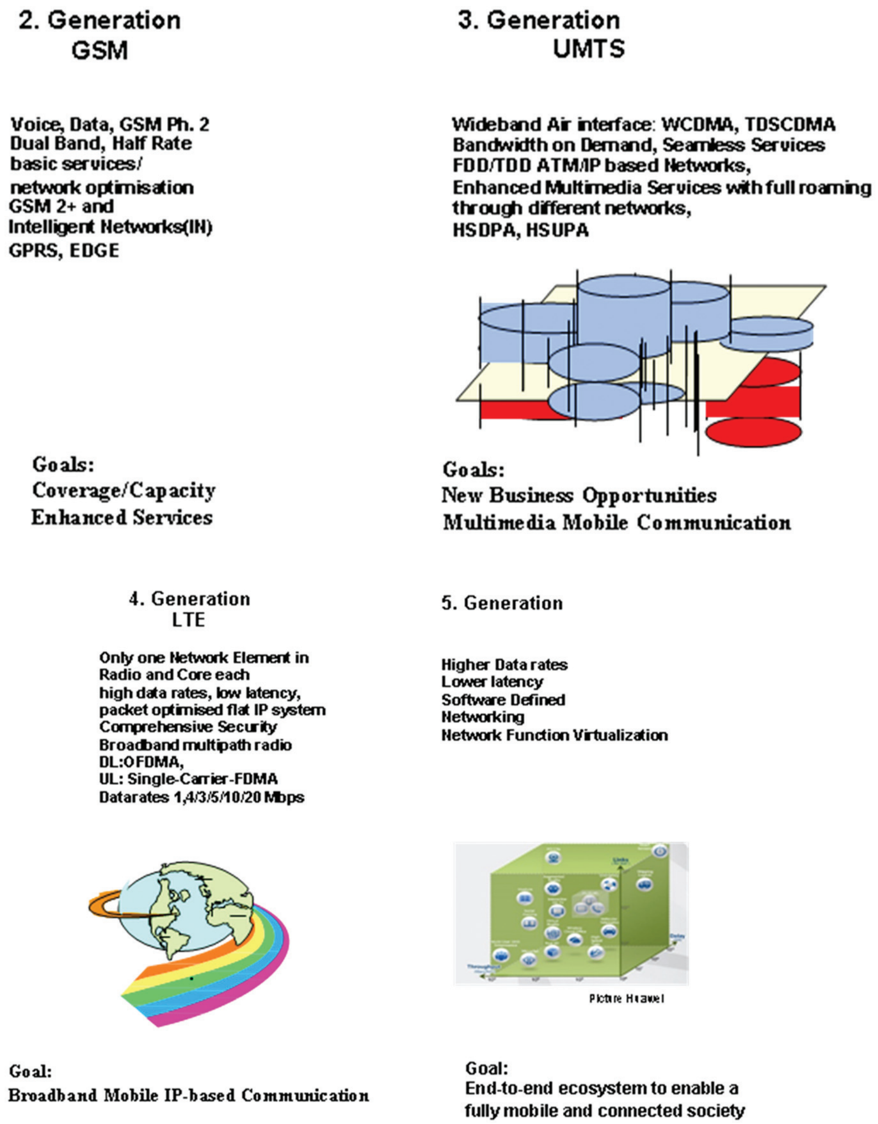

Figure 10.9 Digital mobile networks evolution towards 5th Generation.

The evolution process, which will be chosen, is of importance:

- embark on a linear evolution of today's networks as it was done in the past, or

- adopt a new revolutionary approach, or
- a combination of both.

Traditionally, the 3GPP approach is evolutionary (including backwards compatibility). A pure evolutionary approach may not be sufficient for 5G. To obtain new spectrum for mobile services is essential, but not the whole solution. More efficient use of spectrummust be ensured with licensed, unlicensed and shared access regimes. Opportunities to deliver broadcast content to mobile users and vice versa by exploiting synergies. Network topology and architecture will change:

- cell sizes becoming smaller,
- cells becoming denser (ultra-dense over time),
- traditional "cell" concept will become less relevant in favour of wireless cloud approach,
- interworking with other networks more prevalent (e.g., Wi-Fi offload),
- introduction of device to device working,
- virtualisation of network functions, management and orchestration,
- evolution from hardware to software.

From an economic point of view high demand to reduce CAPEX and OPEX. Decrease radio network energy consumption and CO_2 emissions. Reduce energy consumption per BTS site and use more energy efficient BTS, reduce site power consumption, increase site temperature, use outdoor BTS, optimize energy consumption versus traffic, reduce the number of BTS sites, increase cell coverage, share networks and use renewable energy source like solar cells, wind and hybrid solutions on site like green energy (hydro, wind and bio generated grid electricity). The technical issues to be discussed and analyzed:

- new chip technologies,
- new network architecture with distributed service platforms,
- new hierarchy of cloud platforms, e.g., mobile edge clouds for base stations,
- mini clouds on local level and less central clouds,
- new operating systems and network protocols,
- tactile internet,
- high availability,
- high reliability,
- high security,
- new diversity concept for frequency, place and infrastructure,

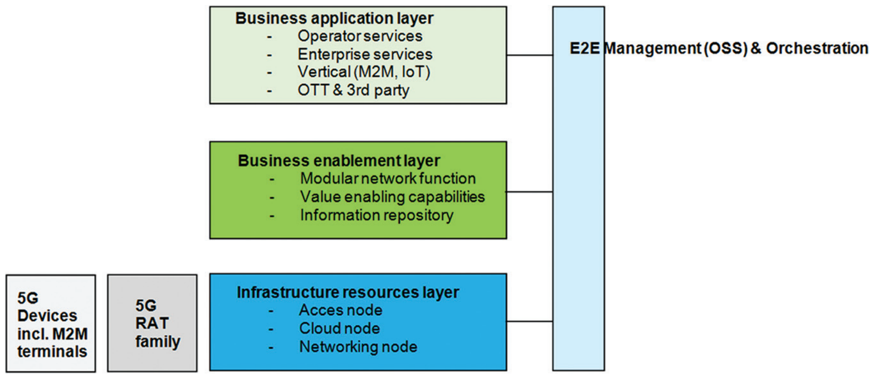

Figure 10.10 5G architecture envisioned by NGMN.

- future machine to machine communication with new authentication techniques to support applications with high security and real time requirements and
- new antenna technique with controlled and intelligent beaming.

Next Generation Mobile Network [8] created an architecture that leverages the structural separation of hardware and software, as well as the programmability offered by Software Defined Networking and Network Function Virtualization. 5G architecture is an SDN/NFV native architecture covering all aspects ranging from devices, (mobile/fixed) infrastructure, network functions, value enabling capabilities and all the management aspects to orchestrate the 5G system. The Infrastructure resource layer contains the physical resources of a fixed-mobile converged network, access nodes, cloud nodes, networking nodes and 5G devices with all kinds of terminals from vertical business applications like M2M terminals. The Business enablement layer contains all functions required within a converged network of modular network function, value enabling capabilities and information repository. The business application layer implies applications and services of the operator, enterprise services, verticals of M2M and IoT and utilisation of 5G networks by 3rd parties. E2E management and orchestration has the capability to manage this 5G network end-to-end and provide an operation support system and self-organizing network capabilities (Figure 10.10).

10.5 New Application Areas for Vertical Industries

The next phase of mobile communication is to integrate industry, energy, mobility, real estate, and its processes. This is widely referred to as machine

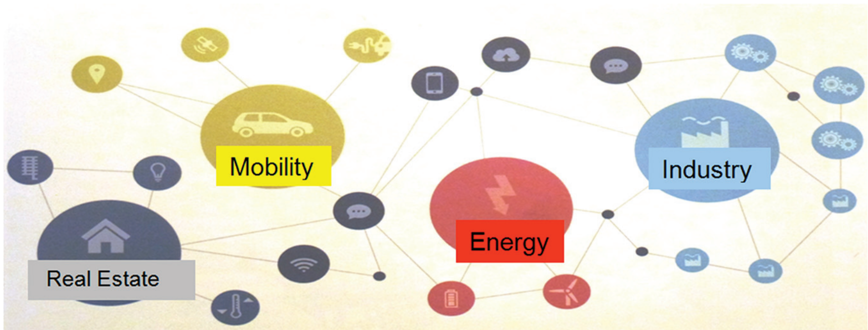

Figure 10.11 New application areas for vertical industries within 5G (Picture VDE).

to machine communication and Internet of the Things. Billions of smart devices will use their embedded communication abilities and sensors to act on their local environment and use remote triggers based on intelligent logic. These devices have different requirements with respect to capabilities, power consumption and cost. IoT will also have a wide range of requirements on networking such as reliability, security, performance (latency, throughput), etc. New services for vertical industries like

- future cars (car-to-car communication, real time navigation, etc.),
- industry 4.0 (plant of the future),
- energy (decentralized energy production, energy transport, energy distribution and
- energy storage) and
- real estate services (metering, consumption control) [8] (Figure 10.11)

will not be limited to connectivity only but can also require enablers from cloud computing, big data management, security, logistics, etc.

10.6 Application Example Decentralized Energy Storage

Energy is a very important resource for the benefit of mankind. In many countries discussions are ongoing how to manage the energy turnaround. An important contribution will build intelligent Smart Grid applications as new services within the communication networks. A decentralized energy storage concept based on Smart Grid applications and a centralized control system shows an example how to contribute to the energy turnaround. Merging power networks and communication networks to intelligent Smart Grids opens a lot of opportunities for future energy resource handling and should motivate researchers to find out the best solutions for the future [9]. For better monitoring and metering, sensors, communication technology as well as distributed real-time computing platforms will be the key technologies for managing various electrical equipment. The herewith handled state parameters are critical for the determination of the current state of the Smart Grids and seen as the success factor for shifting from centralized to decentralized energy system.

This captured information will be used as input for many types of model predictive algorithms whose output supports decisions to achieve the goals of the future Smart Grids. For an appropriate control structure in order to stabilize the grid with a limited mechanical inertia, an architecture based on an appropriate combination of central and decentralized control is needed.

For better predictive models and algorithms improved computer based models and algorithms will be needed. The grid elements such as transmission and distribution lines, voltage and current transformers, flexible AC and DC elements, switches, protection equipment but also all grid users including generators, storage, consumer equipment and behavior have to be extended with digital communication and information features.

A software architecture allowing consumers and market players to compose new services and to satisfy own requirements related to energy services and products thereby using also market interfaces and at the same time supporting the quality and security of supply of the grid based electricity system [10].

The energy turnaround initiated by politics created a high volatility in the energy production based on renewable energy (wind power stations and photovoltaic systems). To integrate renewable energy economically an additional concept of energy storage and energy supply has to be claimed. The proposed concept is a decentralized energy concept and decouples energy production from energy consumption. This is necessary to increase the share of renewable energy in the energy supply in an economical way (Figure 10.12). In the cellars of the real estate industry will be deployed thousands of battery systems. A battery system exists of a battery-farm, a AC/DC inverter and a control- and communication unit. All battery systems are linked to each other and to the control center via the communication unit called Smart Grid. Based on the Smart Grid all decentralized storage system can be linked to a virtual large storage system distributed countrywide. When there is an oversupply of energy the batteries can be loaded and when there is demand the batteries can be unloaded, controlled by the central control center. Intelligent data exchange

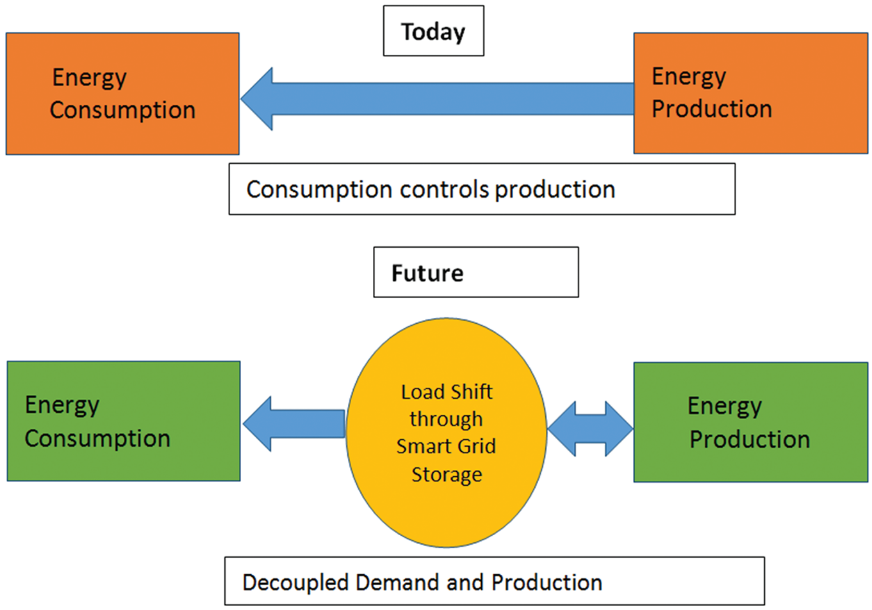

Figure 10.12 Consumption controls production and decoupled demand and production.

between the decentralized battery systems enables the battery systems to organize itself a lot of energy supplies tasks (Figures 10.13 and 10.14).

The Control- and Communication Platform (Figure 10.15) is composed of an industry PC, Linux operating system and the OGEMA Platform [11], developed by Fraunhofer IWES Institute. The applications have to organize

- control of the AC/DC inverter,
- control Battery Management System,
- communication with the central unit,
- communication with the battery systems belonging to the same Micro Grid,
- smart metering,
- recording balancing power,
- remote maintenance,
- security,
- IoT interface.

The revenue model is based on balancing power and tenant electricity. The focus is on real estate industry with huge leverage effect. The top 10 real estate

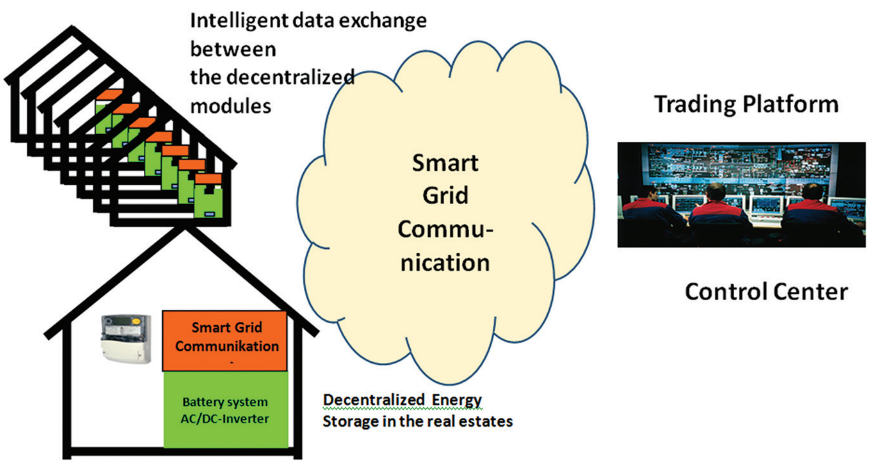

Figure 10.13 Decentralized energy storage linked on a Smart Grid communication to a control center.

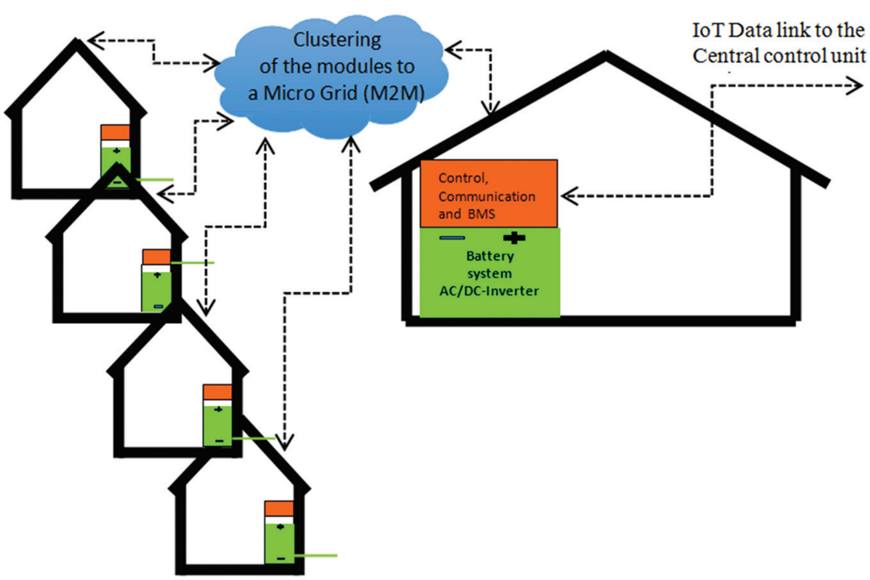

Figure 10.14 Clustering of the battery storage systems to organize itself.

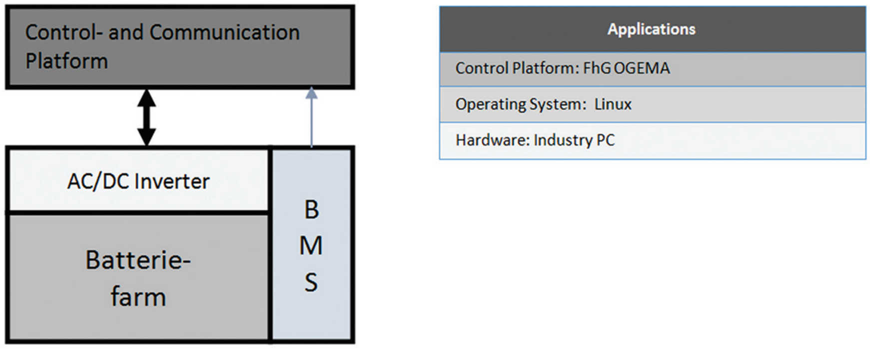

Figure 10.15 Control- and communication platform (IoT interface).

companies in Germany provide base to c. 100,000 buildings and c. 800,000 end users leading to 2,788 GWh power supply per year to end customers.

10.7 Conclusions and Outlook

The future communication standard 5G will change everyday life and economy dramatically. The success of a new generation of mobile communication system is mainly based on new applications to address new market potentials. 5G is expected to address industry, energy, mobility, real estate industry, health, etc. and generate a high number of new applications. Further important topics are security and reliability. It is important to focus on the areas network capability, consistent customer experience, flexibility, efficiency and innovation/8/. Significant investment has to be made in 5G collaborative research programs and within technology companies too. Timing is key and careful alignment is needed between research and standardisation timelines. Measures need to be put in place to ensure that research results lead to high quality standards. Close link between research projects and the most influential players in standardisation has proven to be the best way to ensure close link.

Within the EU research program Horizon 2020 the 5G Public-Private-Partnership (5G PPP) [12, 13] is established, which is focussed on systems with high data rate like video applications, systems for IoT applications and systems with low latency. Additional 5G will support automobile range, transport, manufacturing, banking, energy, smart cities, etc.

Finally, reference should be made to the fact that an excellent new generation will be successful only by learning from the mistakes of the past. Mistakes of the past were no terminals available or too late, less or wrong applications and too much focus on technology and not on business oriented applications. 3G and mainly 4G networks are already on a high level of performance and will be a high competition after 2020, too.

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Walter Konhäuser was born in 1949. He studied electrical engineering at the Technical University in Berlin and finalized with Ph.D. In 2007 he was appointed to Professor for Mobile Communication Systems.

Since joining Siemens in 1982 he has been involved in a variety of assignments. For eighteen years he has worked in the mobile networks business and was CTO within the mobile infrastructure business of Siemens. In 2004 he became President for the WLAN business with worldwide responsibility.

After the merger of Siemens Communication Group with Nokia Net to Nokia Siemens Networks (NSN) in 2007 he became Head of Product Process Deployment and site manager for NSN in Berlin.

Since 2010 he works as independent professional as Executive Consultant and is partner since 2013 at Hoseit-Unternehmensberatung, Berlin and Cologne, where he is working on a decentralized energy storage concept based on Smart Grid applications and a centralized control system to contribute to the energy turnaround.

He is a member of the VDE, the German Association of Electrical Engineers and is Spokesman of the regional VDE organization in Berlin and Brandenburg.