Stages of the Virtual Technical Functions Concept Networks Development

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1 Introduction

Considering mentioned above, it turns out that when implementing the concept of VTF, it is expedient to organize a centralized subscriber database for a particular network, which takes part in the process of using the corresponding virtual technical function. In this case, each switching node of mobile stations must have subscriber data MS, which now are in the zone of its service. When moving a mobile station from the service area of one MSC to the service area of another MSC, they will receive on request the necessary information from a centralized subscriber database that will have access to other databases. In addition, in order to avoid unauthorized access by intruders to the network and possible theft of information or equipment, it is necessary to ensure the ability to verify the access rights of service personnel to the network (authentication) and identification of the relevant equipment. Saving authentication data and a list of serial numbers of the equipment involved also requires a single network of databases, process and store the relevant information. The problems of interaction of mobile communication standards of different generations are becoming more and more urgent because their number has been improving for 10 years. Today the standards of 6-, 7-, 8- are considered, although in practice the technologies of 4-, 5- generations have not yet been fully mastered. The problems of radio frequency resource allocation, the uncertainty of frequency band distribution, and the lack of network infrastructure and subscriber

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equipment remain unresolved. The rapid development of mobile communication means forces operators and providers to search for the most optimal options for the implementation of next-generation mobile telecommunications networks, which could ensure their further technical and economic functioning with the specified quality criteria. To do this, you must have a sufficient level of competence that would allow you to determine the features of such promising technologies. Taking this into account, the concept of the VHE concept was introduced [1, 2] providing for many options, both its own technical implementation and improvement of the concept itself. However, a wide range of options causes serious problems, requires a certain systematization, adaptation of existing networks operating in the telecommunications market and determining the prospects for their further development. The journal “Zviazok” (“Connection”) (no. 4/2010) shows some problems and difficulties in the deployment of future generation networks [3]. To continue the topic, the article highlights the common features and differences in the features of the VHE concept, reflected in various publications. The introduction of LTE technology allows operators to reduce capital and operating costs, reduce the total cost of ownership of the network, expand their capabilities in the field of convergence of services and technologies, and increase revenues from the provision of data services. The network supports MBSFN (Multicast Broadcast Single Frequency Network), which allows the introduction of services such as mobile TV as opposed to DVB-H.

Features provided by LTE:

- High network bandwidth
- High sensitivity
- Support for gaming applications due to low response time
- High interactivity
- Data download speed
- Voice over IP/IMS
- High quality of service
- Expansion of mobile TV channels
- High image quality of mobile TV
- A wide range of options for coexistence of LTE network and networks of previous generations

Comparing the wide range of advanced technologies developed in the technologically advanced countries with the conditions and resources existing in Ukraine, it is easy to conclude that there is a need for a constant careful selection of a limited number of new network technologies, which should focus the attention of all existing telecommunication network operators involved in the market of information and communication services in Ukraine (importers or manufacturers of equipment and software, system integrators, developers, entrepreneurs, regulators).

Given the openness of foreign policy and the market nature of domestic policy, there are practically no restrictions on the use of any network technologies in Ukraine. The only limiting factor is the ratio between the cost of funds for the introduction of technology and the purchasing power of the Ukrainian market of info communication services.

The above fundamental paradigms regarding the technical characteristics of the implemented projects for building mobile telecommunications networks lead to the conclusion that any scenario for the implementation of virtual technical functions with specified quality requirements can be implemented in the concept of SAE/EPS project networks.

Over the past decade, mobile telecommunications systems have become widely used. With the growth of effective demand for mobile telecommunications network services, it became necessary to expand their capabilities. Despite the variety of technologies and high quality of services provided by mobile communication systems of 3-, 4-, 5- generations, they are in principle not able to meet all the requirements of a certain category of users who need to have an ultra-wide range and ultra-high speed of data reception/transmission over global distances with the specified requirements. This category of users includes specialized structures that perform, in addition to providing normal services, also remote control services for certain process that require receiving/transmitting data today for today. These requirements include high capacity, transmission quality, and throughput. The inability to implement these requirements based on existing systems leads to further search for dynamic development of mobile devices. To meet this demand, it became possible only by creating a project of a switching network consisting of several nodes, within which any mobile station (MS) must have access to communication services. MS will be served by the mobile switching centre (MSC) in the service area of which it is located at a certain time. The system approach means that the mobile station is not included in a specific switching node, but directly in a co-existing network system. This feature significantly complicates the organization of the subscriber database, which is the main component in some scenarios of implementation of the concept of VTF (Virtual Technical Functions).

The complexity of the project of organization, monitoring and management of the subscriber database is explained by the fact that MS can move freely, changing the service areas of both base stations (BS) and MSC.

Taking into account the mentioned above and implementing the VTF concept, it is advisable to organize a centralized subscriber database for a particular network, which takes part in the process of forming the corresponding virtual technical function. In this case, each switching node of mobile stations must have subscriber data MS, which at this time are in the zone of its service. When moving a mobile station from the service area of one MSC to the service area of another MSC, these databases get the necessary information from a centralized subscriber database. In addition, in order to avoid unauthorized access of subscribers to the network and possible theft of equipment, it is necessary to ensure the ability to verify access rights (authentication) and identification of equipment. Storing authentication data and a list of hardware serial numbers also requires a network-wide database that stores the relevant information.

2 Literature Review

In networks of the international standard for mobile digital cellular communication of the GSM (Global System for Mobile Communications) standard and in its modifications routing in the mode of data transmission is carried out in the mode of channels switching containing certain shortcomings. The fact is that the Internet traffic is “pulsating” in nature, because the data are transmitted in sharp bursts, not a continuous stream. This type of data traffic is not well suited for circuit-switched networks due to the connection exists even when data are not being transmitted. In addition, it is very expensive for the end user, who pays for the time, not the amount of data transmitted and makes inefficient use of the operator radio interface.

The inconveniences also include a long connection establishment time and the fact that the connections are implemented at a time when the quality of transmission through the radio interface decreases significantly. Through these disadvantages, the transmission of switched packets over circuit-switched mobile telecommunications networks is unreliable and expensive.

In some works variants of construction of concepts are estimated by volume of the transmitted signal information. To theoretical study of the concepts paid considerable attention such scientists as M. Torabi and R. Buhrke [4].

The above sufficiently restrained the introduction of any concept as a video home system (VHS) and VTF.

Taking into account the above mentioned, a new standard was developed to eliminate these problems and to introduce the provision of Internet services in the mobile telecommunications network.

One of the important steps in the evolution of GSM networks was the introduction of packet transmission technology GPRS (General Packet Radio Service).

Based on the improved IMT 2000 project, new requirements for a unified system of mobile telecommunications were formulated [1, 5–9]. Thus, within the framework of the European telecommunication standards Institute ETSI (European telecommunications standards institute), five basic concepts of radio access projects for next-generation mobile telecommunications systems were considered. Two of the five technologies received the most valuable recognition:

- WB-CDMA (wideband code division multiple access)—for paired frequency bands;
- TD-CDMA (time division—code division multiple access)—for odd bands.

The European concept of mobile telecommunications the third generation project systems creation received the name UMTS (universal mobile telecommunications system) [1, 6–9].

The United States, in turn, submitted four projects, which were reduced to such options:

- the first option is based on further improvement of TDMA/AMPS technology (DAMPS, damage-associated molecular patterns);

- the second option offers to gradually increase the capacity of the CDMA One system, moving from the existing infrastructure to the CDMA 2000 technology;
- the third option—two proposals of the United States, which almost completely coincide with the proposals from Europe (UTRA, UMTS Terrestrial Radio Access) and Japan (WCDMA, Wideband Code Division Multiple Access) and in the process of further consideration merged into a single project.

In the Asia-Pacific region, two different draft standards for IMT-2000 were developed: CDMA and CDMA II. These were developed by the telecommunications technology association (TTA) of South Korea. In China, such a project is based on the use of a combined access method and a combination of TDMA and CDMA technologies.

In the framework of the project, IMT-2000 is valid for two migration strategies from existing networks in the mobile telecommunications networks of the project SAE/EPS:

1. Evolutionary
2. Revolutionary

The advantages and disadvantages of these two strategies are discussed in detail in a number of publications [1, 2, 6–10].

When adopting world standards for SAE/EPS project systems, two associations were formed, which were formed in the form of two partner associations:

1. 3GPP—Third Generation Partnership Project
2. 3GPP2—Third Generation Partnership Project 2

For the first time, these partnerships described the challenge of virtual technical functions concepts implementation. However, this description is general and does not contain the list of functions. To date, each of the telecommunications operators is the terminology of the description and implements the project independently.

The main contribution of the 3GPP partnership to the IMT 2000 project is the harmonization of five following projects:

1. UTRA-FDD
2. WCDMA
3. WCDMA NA
4. WIMS
5. CDMA II

The second partner project Association—3GPP2—is a supporter for the evolutionary development of mobile telecommunications 2G two directions in the technologies. The overall picture of the draft standards next-generation mobile telecommunications systems harmonization is shown in Fig. 1.

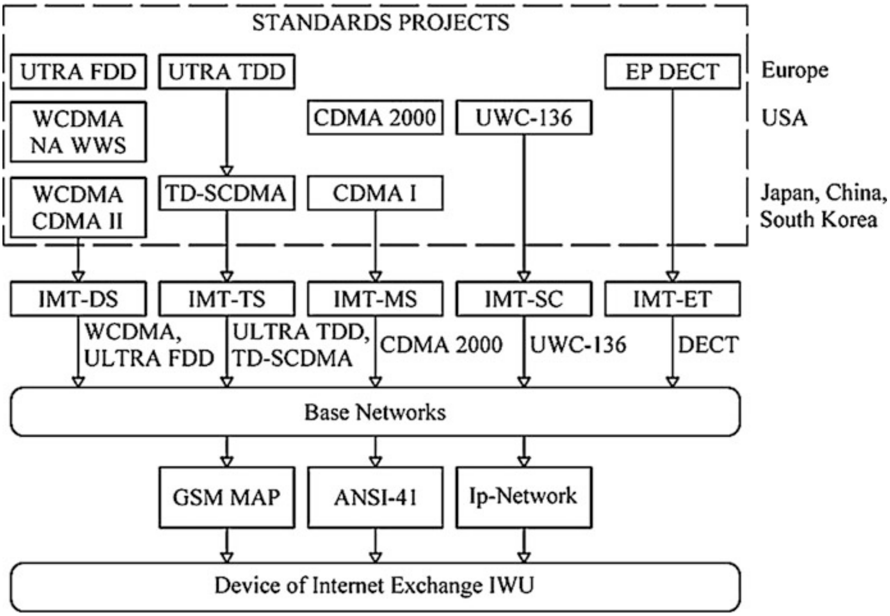


Fig. 1 The architecture of the terrestrial network IMT-2000. (Source: [2, 8–10])

3 Research Methodology

According to many experts, the implementation of SAE/EPS project systems will be preceded by a very long period of their joint existence with third-generation systems. With this in mind, to provide global roaming, as protocols for basic networks in the SAE/EPS project systems, it is planned to use advanced projects of 2G and 3G network protocols (GSM MAP and ANSI-41) and in the future—protocols based on IP-technologies and technologies of intelligent networks (IN) [1, 2, 6–11].

The purpose of this article is the analytical processing of mobile telecommunications networks implemented projects construction.

The above mentioned are the fundamental comments on the technical characteristics of mobile telecommunications networks implemented projects construction. These indicate the potential for the implementation of any virtual technical functions scenario with a given quality in the SAE/EPS project networks.

The authors of the paper analyses the technical capabilities of VTF technology implementation in SAE/EPS networks.

SAE/EPS services enable:

- View the web resources contents or send emails using phones and laptops that support HSPA (High-Speed Packet Access)
- Use HSPA modems instead of DSL modems
- Forward video and music using your existing 3G phones

The SAE/EPS project should be the next step in the development of mobile telecommunications systems. The GSM and WCDMA/HSPA standards are integrated into the SAE/EPS using standardized interfaces connecting the SGSN node (serving GPRS support node) and the enhanced reference network.

The existing concept of quality of service (QoS) for GSM and WCDMA systems is characterized by a sufficient level of complexity. However, the SAE/EPS project has a tendency to implement the concept of QoS, which would combine the simplicity and flexibility of access with support for backward compatibility. The SAE/EPS project proposes the use of a class-based quality of service concept. It provides a simple and effective solution for differentiating different package services. As a conclusion, the authors of the paper can state that the qualitative indicators of the implementation of the VTF concept will be provided by the implementation of the concept of quality of service based on classes.

According to the recommendations of ITU-T (International Telecommunication Union) developed within the IMT-2000 project, the SAE/EPS mobile telecommunications network consists of the following subsystems [2, 10, 12]:

- UIM subsystem (User Identity Module): provides user identification by the network, secure access procedures for both the subscriber and the network, and can perform various functions when performing additional services. UIM functions can be located on a separate card from the mobile terminal (MT) or can be physically integrated into the MT.
- MT subsystem: provides the ability to interact UIM and radio access network (RAN). Like UIM, the MT subsystem can perform various functions when performing additional services.
- Subsystem RAN: provides the possibility of interaction of the MT and the core network (CN) via radio section; can perform various functions when performing additional services.
- CN subsystem: provides the basic functions of the call service process and support for user mobility; can perform various functions in the performance of additional services.

The approach to the implementation of services in the SAE/EPS project, according to ITU-T recommendations, can be based on the concept of an intelligent network [2, 10, 13]. A fundamental requirement to the architecture of intelligent networks is the separation of the functions of service provision from the switching functions.

Each component of the SAE/EPS network participates in the implementation of a certain set of functional tasks and, if necessary, interacts with other functional units of its or other networks.

Each of the functional tasks can be represented as a set of smaller functions. Under the function, it should understand the set of the mobile telecommunications network action components in the process of services implementation once accessed. In this case, the various functions can be located in the same components. The obtained functions can be located in various components of both home (supporting) and visiting network. Thus, there is a set of variants (scenarios) of the VTF concept functional construction structures organization.

Functionally, the core of the SAE network includes four key components. The Mobility Management Entity (MME) module provides storage and management of service information about the subscriber, temporary identification data generation, terminal devices authorization in land-based mobile networks and General mobility management. The UPE subscriber management module (User Plane Entity) is responsible for downstream terminating, data encryption, routing and forwarding of packets. ("Anchor") 3GPP plays the role of a gateway between 2G/3G and LTE networks. Finally, the functions of the SAE anchor are similar to those of the previous component, but serve to support the continuity of service when moving a subscriber between networks that meet and do not meet the 3GPP specifications. Consequently, this indicates the potential for the proposed VTF concept implementation. The generalized scheme of SAE/EPS architecture is shown in Fig. 2.

In Fig. 2, the following notation is taken: Gb, lu, SGI, Rx+, *S*1–*S*7—interfaces; HSS—Home Subs Server; SGSN—Serving GPRS Support Node; PCRF—Policy and Changing Rules Function. 1—MME UPE; 2—EPS core; 3—"Anchor" SAE.

Modern development of mobile telecommunications systems and networks is marked by intensive development and implementation of next-generation systems-LTE-SAE (Long-Term Evolution-System Architecture Evolution) [4, 15, 16]. The

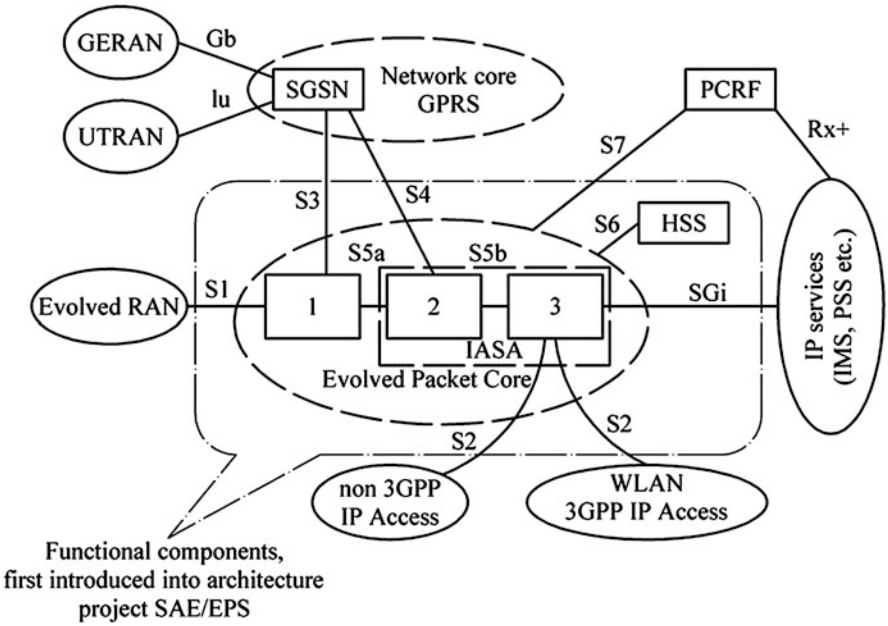


Fig. 2 The main components of the SAE/EPS project architecture. (Source: [14])

ever-growing migration of users between the networks of different Telecom operators requires the support of existing services in their business (home) networks. As an example, in 3G networks, this problem was solved within the concept of a virtual home environment-VHE (Virtual Home Environment), on the basis of which, in turn, the concept of virtual technical functions-VTF (Virtual Technical Functions) was built [7, 17]. The international organization 3GPP (Third-Generation Partnership Project), which initially developed improved versions of CDMA and UMTS, coordinates the research and development of LTE technology. 3GPP specifications defined ways to optimize interaction between networks such as 3G, SAE/EPS (EPS-Evolved Packet System), GSM and CDMA, which allows mobile operators to transfer their networks to new technologies [1, 18]. The beginning of work on the creation of SAE/EPS architecture specifications was due to the processes of transforming the infrastructure of mobile telecommunications networks into non-hierarchical packet switching networks based entirely on the IP Protocol. These works are carried out by the system architecture working group, which is part of the 3GPP consortium. The fundamental principles of the concept for SAE/EPS can be defined as follows:

- Improvement of basic performance indicators (connection time, voice quality, etc.), ensuring acceptable values of the total delay of data transmission over the network.
- Support for basic packet services, including VoIP and presence detection service.
- Support for existing and future access systems, taking into account the needs of the user and the technical policy of the operator, ensuring correct billing when the subscriber changes access technology.
- Support for access control functions to information resources (identification and authorization).
- Support for consistent QoS parameters throughout the network, especially when transmitting traffic between different domains and networks.
- Ensuring continuity of service for mobile subscribers;
- Ensuring confidentiality and protection of information when it is transmitted in the network.

According to ITU-T recommendations developed within the framework of the IMT-2000 project (International Mobile Telecommunications-2000), the SAE/EPS mobile telecommunications network consists of the following subsystems [8, 19]:

- UIM (User Identity Module) subsystem: provides user identification by the network, secure access procedures for both the subscriber and the network, and can also perform various functions when performing additional services. UIM functions can be located on a separate card from the mobile terminal (MT) or can be physically integrated into the MT.
- MT subsystem (Mobile Terminal): provides the possibility of interaction between the UIM and the RAN radio access network. Like UIM, it can perform various functions when performing additional services.

- RAN subsystem (Radio Access Network): provides the possibility of interaction between the MT and the base network (CN) via radio link; can perform various functions when performing additional services.
- CN subsystem (Core Network): provides the main functions of the call service process and support for user mobility; can perform various functions when performing additional services. The approach to the implementation of services in the SAE/EPS project, according to ITU-T recommendations, can be based on the concept of an intelligent network [9, 20]. A fundamental requirement for an intelligent network architecture is the separation of service delivery functions from switching functions. Each component of the SAE/EPS network participates in the implementation of a certain set of functional tasks and, if necessary, interacts with other functional units of its own or other networks. Each of the functional tasks can be represented as a set of smaller functions. A function should be understood as a set of actions of a mobile telecommunications network component in the process of implementing a service with a single access to it. In this case, various functions can be located in the same components. The resulting functions can be located in various components of both the home (support) and business network. Thus, there are many options (scenarios) for the organization of structures for the functional construction of the VTF concept. Functionally, the core of the SAE network includes four key components:
- The MME (Mobility Management Entity) mobility management module provides storage and management of service information about the subscriber, generation of temporary identification data, authorization of terminal devices in terrestrial mobile networks and General mobility management.
- The UPE (User Plane Entity) subscriber management module is responsible for downlink termination, data encryption, routing and packet forwarding. In this case, the “Anchor” 3GPP plays the role of a kind of gateway between 2G/3G and LTE networks. The SAE anchor functions are similar to those of the previous component, but serve to maintain service continuity when a subscriber moves between networks that meet and do not meet 3GPP specifications. The fundamental difference between mobile telecommunications networks of the 4G generation from mobile networks of previous generations is the ability to provide high-speed data transmission on the following radio stations:

  2048 Mbit/s—for office work
  384 kbit/s—for pedestrians
  144 kbit/s—for mobile subscribers

Higher transmission speeds provide users of these networks with more services. First, this applies to mobile access to Internet resources at a speed that satisfies the consumer. Mobile telecommunications networks of the SAE/EPS project allow you to transmit and receive large amounts of data, video images, music files and other multimedia information in real time [10]. At the same time, the services of networks of previous generations, which have already proven themselves, should be actively used in the networks of the SAE/EPS project, thereby confirming the fundamental need to implement and expand the concept of VTF. These services, within the concept of VTF, first of all, need to include the service of short message exchange SMS (Short Message Service). An alternative to the already proven SMS and EMS (Enhanced Message Service) is the multimedia message service MMS (Multimedia Message Service). As a conclusion, it can be noted that in accordance with the standards of ITU-T, ETSI and 3GPP in the mobile telecommunications networks of the SAE/EPS project, it is advisable to use the VTF concept to enable its subscribers to use the services of the home network while being outside it—in the business network. The main task of each SAE/EPS network operator should remain the task of providing any subscriber with the usual set of services while roaming, that is, to provide 100% support for the usual functions, despite the fact that such functions will be "virtual", that is – unusual for a business network. The number and variety of services that can potentially be implemented using such systems are very large, which is attractive for both subscribers and mobile operators.

As can be seen from Fig. 2, the functional elements can be physically combined or distributed over the network. It all depends on the features of the demanded products used and the network itself. For example, "Anchor" 3GPP is allowed to be placed together with the subscriber management module, although this is not a requirement. In addition, MME and UPE modules can be combined or located in different network nodes.

The fundamental difference between the fourth-generation mobile telecommunications networks and the previous-generation mobile networks is the ability to provide a higher speed of information transmission. The continuation of the logical development of high speeds will be the application of standards of the fifth, sixth, and seventh generations. Many companies have already announced modems for such networks that use additional high-speed channel capabilities, which, theoretically, are 326.4 Mbit/s for "download", and 172.8 Mbit/s for return.

As an example, according to the ITU-T guidelines, the 5G network speed should have a peak data rate of 20 Gbit/s for the downlink and 10 Gbit/s for the uplink. Latency in a 5G network can be up to 4 ms in a mobile scenario, and can be up to 1 ms in Ultra Reliable Low Latency communication scenarios. Not only will physical users be connected to each other, but also technological devices (cars, automobiles, city infrastructure, public security, and more) will be able to interact with each other [11, 21]. The speed in the standards of higher generations will be higher several times compared to the standards of lower generations. Now that 7G mobile phone technology is coming, which will be two or three times faster than the 4G standard, there is no doubt that we will need to model and implement new MS technologies.

Higher transmission rates provide more services to users of these networks. First, it concerns mobile access to Internet resources at a speed that satisfies the consumer. SAE/EPS mobile telecommunications networks allow you to transfer and receive large amounts of data, video images, music files and other multimedia information in real time. At the same time, the services of previous generations networks, which have already proven themselves, should be actively used in the networks of the SAE/EPS project. Thereby confirming the fundamental need for the introduction and expansion of the VTF concept. These services, within the framework of the VTF concept, first, should include the service of short SMS (Short

Message Service). As an alternative to the already proven services of SMS and EMS (Enhanced Message Service) came multimedia messaging service (MMS). However, when different standards interact, problems arise (and will continue to arise in the future) to optimize the transition from one standard to another, when users are in different coverage planes, with different standards.

Services provided by modern contact centres (call centres) have become very popular in mobile telecommunications. The introduction of contact centres is one of the many ways to organize effectively interaction with their customers when they have any questions or problems: this is their main function in the VTF concept implementation.

The main task of each SAE/EPS network operator is to provide any subscriber with the above-described usual set of services when he is roaming, that is, to provide 100% support for the usual functions despite the fact that such functions will be "virtual", that is unusual for a visiting network. The physical level of the draft standards for "higher generation" mobile communication systems should provide not only higher data rates, but also better spectral efficiency compared to previous standards, frequency compatibility when switching MS during its operation in different regions, which may have equipment with different characteristics.

As an example, the development of fifth-generation technologies provides a certain set of "input" characteristics that serve as a guide for the new standard. For example, compared to the best existing LTE networks, the data transfer rate in 5G networks should be 10–100 times higher, the response time—5 times less, the network should support 100 times more devices. It is assumed that the sequential transition from fourth-generation to fifth-generation networks will take longer than the transition from 3G to LTE.

The number of devices that are connected to the Internet and among themselves is constantly increasing. There is a need for better networks that can ensure the interaction of various standards of mobile communication systems, taking into account their further prospects for improvement. The new generation of networks opens up new opportunities in many areas—from improving the efficiency of production processes, improving safety on the roads and in the city as a whole to improving public services and a cleaner environment.

The mass appearance of 5G solutions is unlikely to take place before 2020–2022, because Telecom operators need to optimize the cost of advanced technologies and related equipment, and determine the priority business tasks in a new area for them. Today, TM operators must also provide for the interaction of "higher" standards that will be developed and are being developed with "lower" standards that have already been implemented and are in operation.

According to experts from telecommunications networks, in order to successfully implement systems of different generations for a number of applications, the frequencies of "higher" generation standards with a low-frequency part of the spectrum (below 6 GHz) will be needed simultaneously.

It is expected that low frequencies (e.g., 3.4–3.6 GHz) and wide bands will allow mass availability of speeds up to 100 Mbit.

Low frequencies and good coverage will ensure good permeability in the premises of various technologies, which is important in order to achieve mass-market expansion. This applies primarily to the 700 MHz band and, to a lesser extent, the 3.4–3.8 GHz band. This range can be used for applications in mobile devices to connect to "higher" networks. As noted above, when implementing the concept of VTF, it is advisable to organize a centralized subscriber database for a particular network, which takes part in the process of using the corresponding virtual technical function. In this case, each switching node of mobile stations must have subscriber data MS, which now are in the zone of its service. When moving a mobile station from the service area of one MSC to the service area of another MSC, they will receive on request the necessary information from the centralized subscriber database, which must have ultra-high power and the ability to interact with the centralized subscriber databases of the global network. However, this issue requires a separate study and study. The number and variety of services that can potentially be implemented using such systems is very large, which is very attractive for both mobile telecommunications subscribers and mobile operators. It should be noted that the list of services provided is growing rapidly and steadily. Some services may be in demand, which at first glance will not have an economic effect, but over time, when actively served in advertising brochures, such a service may acquire the effect of "explosion", which will provide rapid coverage of the expensive costs of upgrading the next standard. As it was already noted earlier, one or more service devices (components) of both the business and home (supporting) network of subscribers can participate in the implementation of a certain service. The complexity of obtaining is due, first, to the variety of options for building alarm networks in which applications are transmitted between these OP, and the large volume of alarm systems used on these networks. Today, the main alarm system in cellular communication networks is the ACS system No. 7, which according to ITU-T recommendations [3, 11] can be used in mobile telecommunications networks of the SAE/EPS project. At the same time, the proposed approach to determining the value in the network of ACS No. 7 can be used in any other packet-signalling network, built based on a family of other protocols may have different concepts with different components, especially in the protocols of mobile communication standards of "higher generations".

4 Results

Currently, there are two concepts providing additional services in mobile telecommunications networks:

1. Nodes of the services (Service nodes)
2. "Classical" intelligent communication network IN

The first one is used for the above-mentioned services organization: SMS, EMS, MMS, contact centre services, etc. Main value of the second concept for mobile telecommunications networks is the lists of services capability set (CS). So far, the main idea is to separate the processes of traditional switching from the procedures for the new services provision. The relevance of this idea makes it attractive for mobile telecommunications networks of the SAE/EPS project, focused on providing additional services to the subscriber.

The architecture of IN and the mobile telecommunications networks are very similar (Fig. 3). However, mobile telecommunications networks are not able to provide adequately the independence principle from services inherent in the concept of IN [1, 2, 5–10, 13, 14]. Given the above, the mobile telecommunications operators seek to seize the advantages offered by the concept IN. The implementation of the same service in IN occurs through a certain sequence functions execution. Under the function, it should be understood the mobile telecommunications network set of action components in the process of services implementation at a single address to the application. At the same time, during the service implementation, each component can perform one or more functions. One of the main advantages offered by mobile telecommunications networks is free subscriber possibility movement from its zone to one or another zones served by other mobile telecommunications networks operators. At the same time, the subscriber would like to keep his personal services set (profile) in other networks (to be able to roaming services). However, unlike wired networks, in mobile telecommunications switches, trigger points and

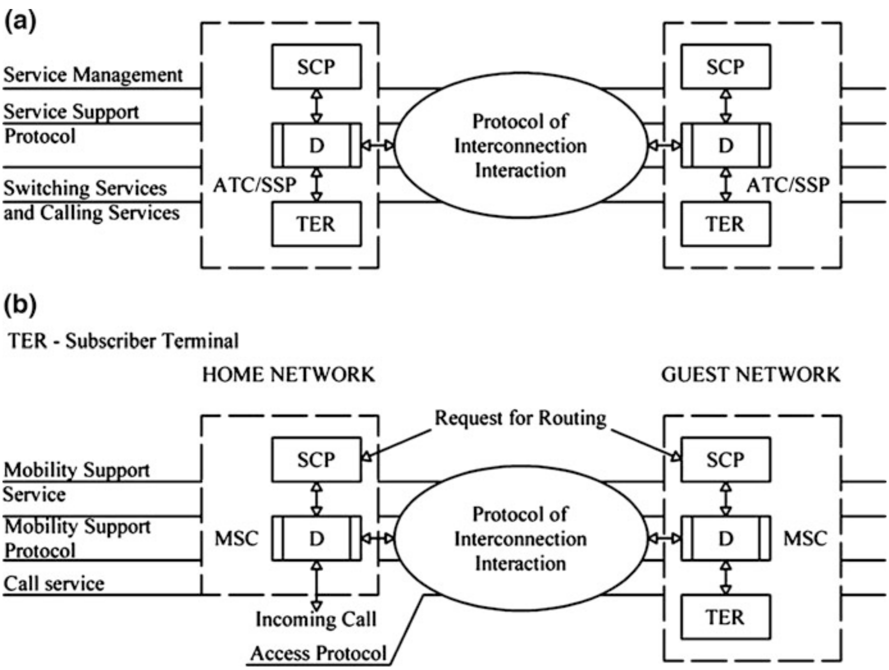
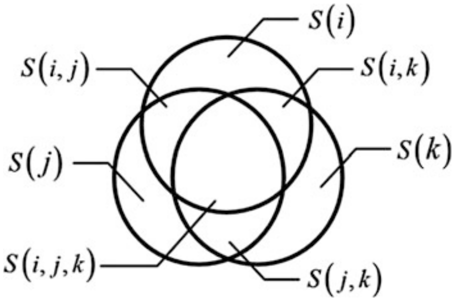


Fig. 3 Architecture of IN (**a**) and mobile telecommunications networks (**b**). (Source: [14])

Fig. 4 Model of service coverage in project networks SAE/EPS. (Source: [14])



service profiles are not represented as static data, but are defined at registration. The possibilities of home and visiting networks can be different, which will affect the list and characteristics of services that can be offered to the user that has moved to the visiting network [13, 14].

For the Fig. 4 abstract model with three mobile telecommunications of the fourth generation systems belonging to different operators is shown.

Each of the three SAE/EPS project systems shown in Fig. 4 has its own set of services: $S(i)$, $S(j)$, $S(k)$ and are shown by the circles. The intersections of these circles are services that are the same for these networks. As the number of SAE/EPS project systems increases, the overall platform $S(i, j, k)$ decreases. According to the standards ITU-T ETS1, 3GPP in the mobile telecommunications networks of the SAE/EPS project, to enable its subscribers to use the functions of the home network while outside it, that is, in the visiting network, the previously mentioned VHS concept was introduced, the list of functions of which was quite limited and had a declarative character. The degree to which the proposed VTF concept can meet the actual needs of subscribers will be extremely high and will depend only on the degree of cooperation between operators, their technical capabilities, compatibility of user equipment, etc. In addition, the SAE/EPS project systems twill offer their subscribers a global roaming service should support VTF, if these systems have the capabilities of a subscriber service similar to the VHS service from the very beginning.

The physical layer of the SAE/EPS project systems provides not only higher data rates, but also better spectral efficiency compared to the “lower” standards. As already noted, the interaction of various mobile communication standards will require the development and implementation of appropriate equipment.

In the process of implementing the VTF concept, a certain number of services are performed using hardware and software. As mentioned earlier, in the process of implementing the service, each component can perform one or more functions. The composition of functions depends on many factors, for example, on the service itself, the actions of subscribers, etc. The resulting functions can be located in various components of both the home (support) and visiting network. In this case, the various functions can be located in the same components. Thus, there is a set of variants (scenarios) of the VTF structurally functional construction concept organization. Since there are various options for structurally functional construction of the VTF concept, then at the stage of its design there is a problem of choosing one or another option – a scenario for the concept implementation.

To solve this problem, it is necessary to have a tool that allows evaluating the options for building the VTF concept. However, as noted in scientific publications on this topic, often are only the scenarios for the implementation of such concepts and their analysis is not done. In some other works, the volume of signal information circulating between the components of mobile telecommunications networks acts as a criterion for evaluating the construction options. At the same time, less attention is paid to assessing the impact on the quality of services scenario choice, and hence on the degree of these end-user services satisfaction [13–15, 21]. In this case, there is a need for almost simultaneous interaction of different components in different mobile communication standards.

5 Conclusions

The state and prospects of mobile communication systems development are considered. The definition of concepts, individual scenarios implementation is given. An abstract model with three fourth-generation mobile communication systems belonging to different operators is shown. Considering the results of preliminary studies, it is concluded that in the concepts implementation, it is advisable to organize a centralized subscriber database for a specific network, which takes part in the process of a virtual technical function providing.

The general picture of the next generation's mobile communication standards harmonization is formed. The general purpose of the study and partial tasks that need to be addressed are the further concept developments of telecommunication networks of mobile communication (fifth generation).

The improvement of virtual technical functions will ensure a strong market position in telecommunication systems.

The latest network technologies are a natural product of scientific and technological progress, which is rapidly being carried out by the technically developed countries of the world to obtain the advantages of leadership in the global distribution of labour. Ukraine is forced to play the role of an importer of the latest network technologies, paying for their import with other goods or services of its own production. This fee will be greater the more complex and more ready-to-use are the means are in which network technologies are implemented. The most effective technologies that should be used for the development of info communication in Ukraine should be considered further research of mobile communication standards of the latest and future generations, research, testing and evaluation of a variety of new technologies that determine the development of telecommunications in the world.

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References

1. FY 1998 National Communications System, 1998, http://www.ncs.gov/library/reports/ncs_fy1998.pdf
2. ITU-T Recommendation F.115, Service objectives and principles, 1995
3. P. Bakhovskyi, M. Yevsiuk, Specific aspects of the development of mobile telecommunications network. Perspective Technologies and Devices, Issue 13 (2018)
4. M. Torabi, R. Buhrke, Third-generation mobile telecommunications and virtual home environment: A prioritization analysis. Bell Labs Techn. J. **3**(3), 50–62 (1998)
5. D. MacDonald, Teletraffic performance in intelligent network services. ITC-14, 1994
6. R. Andrade, L. Logrippo, MoRaR: A Pattern Language for Mobility and Radio Resource Management, 2004, http://www.site.uottawa.ca/~luigi/papers/06_andrade_logrippo.pdf
7. ITU-T Recommendation Q.I751, Internetwork signalling requirements for IMT-2000 capability set 1, 2000
8. ITU-T Recommendation Q.I741.1, IMT-2000 references to release 1999 of GSM evolved UMTS core network with UTRAN access network, 2002
9. ITU-T Recommendation Q.I741.2, IMT-2000 references to release 4 of GSM evolved UMTS core network with UTRAN access network, 2002
10. ITU-T Recommendation M.816-1, Framework for services supported on International Mobile Telecommunications-2000 (IMT-2000), 1997
11. Electronic resource, https://www.sdxcentral.com/5g/definitions/imt-2020, 2019
12. ITU-T Recommendation Q.1702, Long-term vision of network aspects for systems beyond IMT-2000, 2002
13. P. Bakhovsky, Intellectual network: Socio-economic concept, in *Conference Modern Problems of Telecommunications 2008*, Lviv (2008), pp. 65–68
14. P. Bakhovsky, *Materials of the Dissertation Are to Obtain a Scientific Degree of the Candidate of Technical Sciences* (Ukrainian State Academy of Railway Transport, Kharkiv, 2010)
15. M. Bawa, D. Cagáňová, Selecting network protocols for internet of things based upon innovation and knowledge management. J. Telecommun. Syst. Manag. **7**(2), 1–4 (2018)
16. P.F. Bakhovskyi, E.D. Amirkhanov, Y.I. Toroshanko, K.V. Khmara, Analysis of the economic feasibilities of introduction of technologies of VTF in the networks of SAE/EPS. Scientific Notes of the Ukrainian Research Institute of Communication, vol. 1(41) (2016)
17. P.F. Bakhovskyi, V.O. Hrebennikov, Trends in the development of the telecommunications market in Ukraine and proposals for its improvement. Scientific Notes of the Ukrainian Research Institute of Communications, vol. 3(5) (2008)
18. 3G Evolution Horizons: Architectural Aspects, http://osp.ru/nets/2007/16/4626460/
19. Y. Toroshanko, Y. Selepyna, N. Yakymchuk, V. Cherevyk, Control of traffic streams with the multi-rate token bucket, in *International Conference on Advanced Information and Communications Technologies, AICT 2019* (2019), pp. 352–355
20. M.A. Vinohradov, P.F. Bakhovskyi, Investigation of a non-stationary random access network with a dynamic protocol under heavy load conditions in the framework of the VTF concept implementation. Scientific Notes of the Ukrainian Research Institute of Communications, vol. 4(12) (2009)
21. D. Cagáňová, M. Bawa, D.R. Delgado Sobrino, A. Saniuk, *Internet of Things and Smart City*, 1st edn. (Uniwersytet Zielonogórski, Zielona Góra, 2017), p. 138