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Review

Fusion of Telecommunications and IT Services Boosted by Application Programming Interfaces

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Abstract: Our long journey on the road of telecommunications is continuously evolving. We have experienced several technological changes, modernizations, optimizations, and various mergers in the past decades. Virtualization and 'cloudification' of legacy telecommunication equipment has made communication networks not only more flexible, but also opened new doors. Brand new types of services have become available thanks to the ongoing fusion of the two domains of telecommunications and IT (Information Technology). This overview paper first discusses the evolution of services with an enhanced focus on mobile networks. Then, the possibilities offered by IT are shown. Finally, some examples are given of how Communication Service Providers and end users can benefit from these recent changes.

Keywords: communication services; cloud; API; CAMEL; INAP; IT; TAS; VoLTE; IMS data channel

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1. Introduction

The landscape of fixed and wireless telecommunications has changed extremely quickly over the past three decades. Communication Service Providers (CSPs) continuously face challenges when operating various hardware (HW) and software (SW) from different equipment manufacturers in their multi-functional and multi-layered networks.

On the one hand, the introduction of innovative technologies and new services has transformed legacy systems into a more and more sophisticated network architecture. As an example, and without completeness, an evolving network scenario is shown in Figure 1. The network contains fixed and mobile subscriber access technologies and different core network types. Such a CSP network environment can simultaneously serve consumer, industrial, and enterprise subscribers requiring various wired and wireless services. In several countries, including Hungary, third-generation (3G) mobile sunset projects have already started to switch off 3G NodeBs (NBs) completely. Similarly, the Plain Old Telephone Service (POTS) fixed lines of legacy Public Switched Telephone Networks (PSTNs) are in practice being continuously replaced by mobile or fixed VoIP (Voice over IP) solutions. The complex meshed network of Figure 1 can be divided into three main parts: subscriber access; cell sites, controller nodes, and backhauling; and, finally, the core network (horizontal scale). The various subscriber access methods are fixed, nomadic, or mobile (vertical scale in Figure 1).

Since the appearance of smart devices and with the growing demand for the IoT (Internet of Things) and machine-to-machine communications (M2M), subscriptions are growing enormously [1,2]. Subscribers are not any longer only human users using the network for simple telephone voice calls. Industry, transportation, modern agriculture, education, medicine, robotics, etc. all require data connections [3–6]. The User Equipment (UE, either fixed or mobile) at the end of the data links can be sensors, machines, metering devices, cameras, vehicles, robots, or any other remote-controlled equipment. A massive rollout of 5G (fifth-generation mobile systems, also called New Radio, NR) systems is already ongoing in several countries to serve these new demands. In Figure 1, 5G core and NR are marked in light blue, and phase-out technologies are marked in gray.

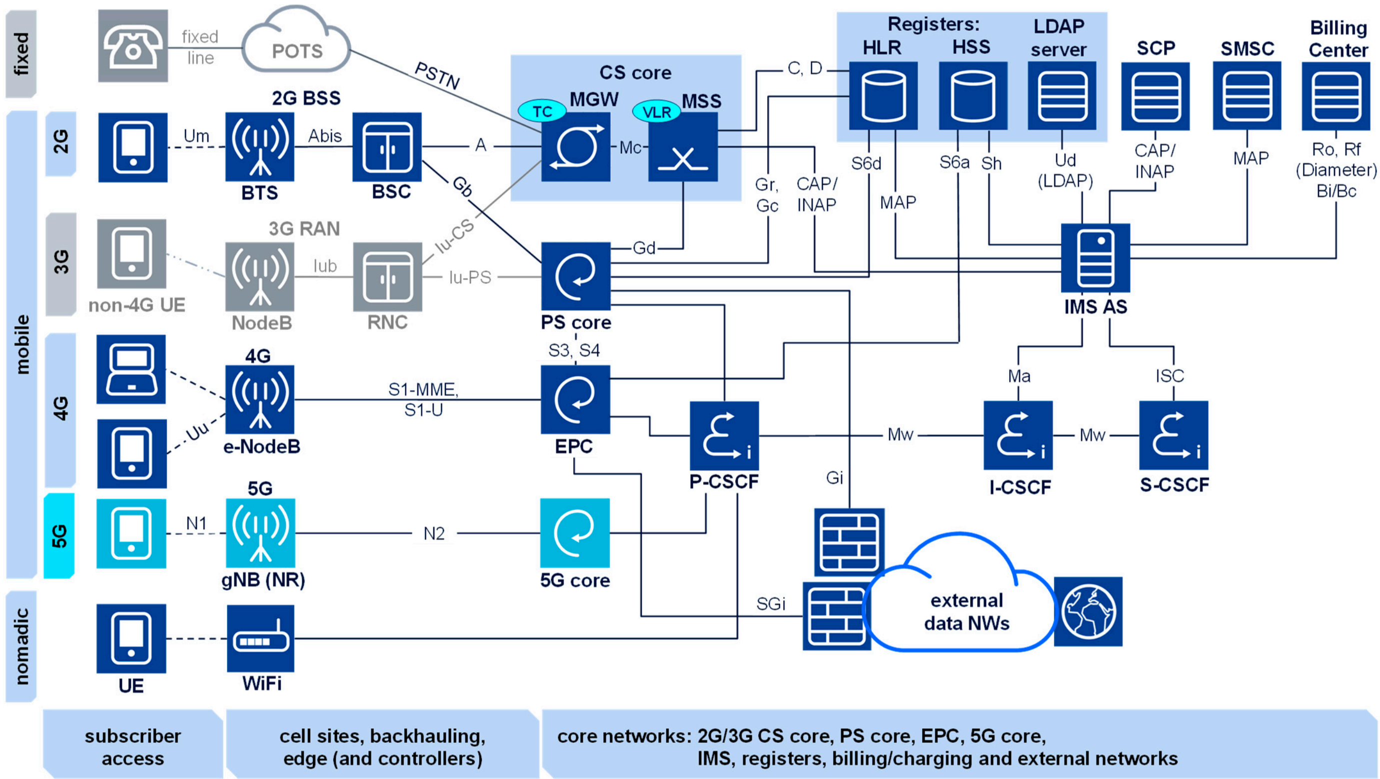

Figure 1. The evolving telecommunication network as a mesh of various fixed and mobile access technologies and core networks.

On the other hand, deployments of new technologies and services always provide the inherent possibility of optimizing, modernizing, or merging network layers towards a converged or 'flattened' architecture. The convergence and simplification possibilities arise at different layers: at the equipment level (either HW or SW) and at the Network Element (NE) and network levels. Finally, as shown in this paper, convergence has started even at the services level. Several important trends have paved the way for service convergence in the past years. Without completeness, a few important milestones are listed as follows:

- Convergence of fixed and mobile networks (FMC, Fixed–Mobile Convergence);
- Sunset of earlier Radio Access Technologies (RATs), e.g., 3G systems in Europe and 2G (second-generation) and 3G in America and Asia [3];
- Introduction of new RATs, i.e., 4G (fourth-generation), LTE-A (Advanced Long-Term Evolution), and 5G [4–7];
- Intensive research and standardization of 5G and beyond and future 6G (sixth-generation) mobile systems and Open RAN (Radio Access Network) solutions [4–6,8,9];
- Access-agnostic solutions expanding the coverage of various 'trusted' mobile generations with WiFi (Wireless Fidelity) access, which has traditionally been treated as 'untrusted' [10,11];
- Continuous introduction of new protocols and interfaces (e.g., Diameter for Ro/Rf to replace the legacy Bi/Bc charging interfaces) [7];
- Replacement of legacy transmission and transport solutions and legacy protocols (e.g., TDM/PDH/SDH/ATM) in all segments, including User Plane (UP), Control Plane (CP), management plane, and synchronization [3,12,13];

- Modernization projects targeting 'all-IP' networks and Software-Defined Networking (SDN) [13–16];
- Replacement of earlier 'non-cloud friendly' interfaces and protocols and introduction of Service-Based Architecture (SBA) and service discovery instead of rigid 'fixed configurations' that are used in legacy telecommunications [17];
- Protection of network functions and interfaces to achieve more resilient operation and high availability (from redundancy methods and anti-affinity rules to distribution in a geo-redundant Telco cloud) [18,19];
- Cloudification: migrating physical network elements and Physical Network Functions (PNFs) to Virtualized Network Functions (VNFs) and Cloud-native Network Functions (CNFs) [8–10,17–24];
- Flexible resource management of cloud-based VNFs and CNFs, scaling, and network slicing [24–30];
- Continuous capacity expansions and upgrades in both access and core network domains, introducing new business models, such as private and non-public networks [3,5,12,23,31,32];
- Convergence of Data Center and IT (Information Technology) with telecommunications on HW and SW infrastructure and service layers [18–22,33–35].

After this short introduction, in Section 2, the development of legacy telecommunication services is reviewed. Section 3 shows replacement options for existing Intelligent Networks (INs) services. Section 4 discusses the fusion of IT and telecommunication domains, which is illustrated with Nokia TAS. Several Open API and IMS Data Channel use cases are given. Finally, Section 5 concludes this paper, and useful references are listed.

2. Developing Telecommunication Services—From INAP to CAMEL

In legacy PSTN networks, digitalization of telephone exchanges opened the possibility of implementing various telephone call-related services. Originally, call-related services were integrated into the code of the digital exchanges, i.e., in the stored program itself. In the first 2G and 3G systems, the Mobile Switching Center (MSC) played the role of the digital telephone exchange. With the introduction of Release 4 networks, the MSS (MSC Server) took over the function of the MSC in combined 2G/3G networks (Figure 1). Similarly to the fixed networks, at the beginning of mobile telephony, call-related services were implemented by the switches too. These services were hardcoded to the business logic (BL) of the 2G/3G switches across the entire network. With the arrival of Intelligent Networks, services have been centralized to a dedicated platform [36–39]. The service logic (SL) was decoupled from the business logic of the telephone exchange into an external entity: the Service Control Function (SCF). As shown in Figure 2, the SCF had access to the Service Data Function (SDF), a database that could be managed by the Service Management Function (SMF). The telephone exchanges and Intelligent Networks were communicating with each other using the SS7 (Signaling System No. 7) stack.

The telephone exchange can report certain call events (e.g., call initiations, call answers, and call disconnects) to the SCF platform. So, SCF can instruct the switch on the outcome of the call, e.g., continue, release, or redirect a call. SCF can initiate user interaction, send additional charging-related data, and can also control the call duration for prepaid subscribers. Typical telecommunication service use cases include, for example, the following:

- Prepaid services, where payment precedes the use of the service. The purchased credit is used to pay for communications services when the service is used. When the credit is almost fully consumed, then the subscriber is warned by a tone within the call, and when it is fully consumed, further access is denied by the cellular network or by the Intelligent Network;
- Interactive voice response menus;
- Sequential alerting of devices of a small office;
- Private numbering plans for enterprises.

In the application layer of the interface between the switch and the SCF, two main alternatives have become widespread. The Intelligent Networks Application Part (INAP) has been standardized for fixed telephony and later adapted also for mobile networks [36–39]. To avoid incompatibility of different vendor-specific implementations and to address roaming and mobility, the ETSI (European Telecommunications Standards Institute) and 3GPP (3rd Generation Partnership Project) specified a new service invocation interface for mobile networks. The Customized Applications for Mobile networks Enhanced Logic (CAMEL) became standardized by 3GPP and ETSI. The CAMEL Application Part (CAP) has evolved from the INAP to meet the needs of mobile networks and extended the IN framework to GSM and 3G networks, as shown in Figure 3.

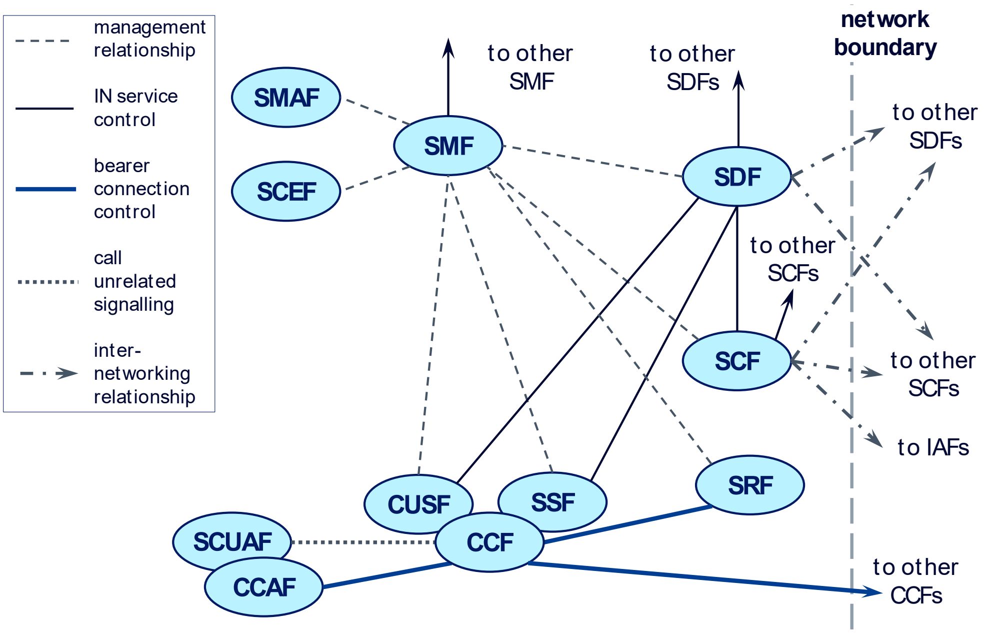

Figure 2. General IN architecture with decoupled business and service logic [36].

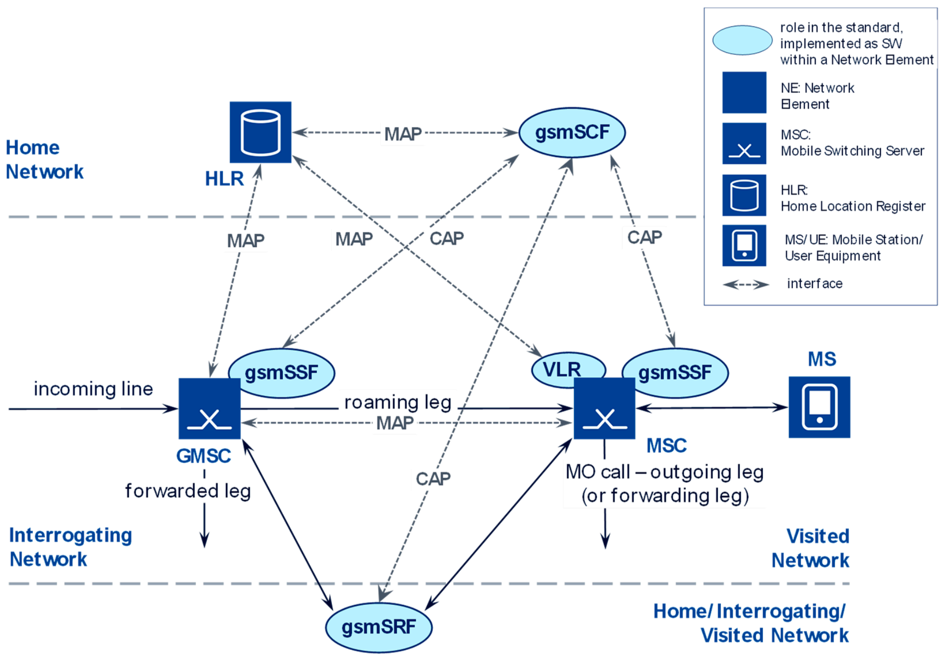

Figure 3. 2G/3G mobile service logic over CAMEL with decoupled business and service logic [36].

The CAMEL framework provided tools for Mobile Network Operators (MNOs) to define additional features for standard GSM/UMTS (Universal Mobile Telecommunications System) services. The protocols are described in a series of ETSI technical specifications: CAMEL specifications have been published in four consecutive phases [40–44]. Each new phase builds upon the capabilities of the previous one. The standards have been issued first for GSM NSS (Network Switching Subsystems). In fact, the first two phases were defined before 3G networks existed. The standards added IN services to GSM networks, but they were applicable to 2.5G (2G with Enhanced Data rates for GSM Evolution, EDGE) and 3G networks later too. Then, CAMEL was extended for UMTS core networks: Phase 3 was defined for 3GPP Release 99 and Release 4 as a common 2G/3G specification. Phase 4 was defined as part of 3GPP Release 5. Each CAP phase provides the set of operations and procedures needed to support the corresponding CAMEL phase requirements, as defined in the specifications [40–44]. In-line with other GSM specifications, the later phases build new features on top of the previous phases. Many services could be created using CAMEL. It has been particularly successful in cases when subscribers were roaming outside their home network. Good examples are prefix-free dialing, when the dialed number is the same no matter in which country the call is placed by the subscribers, parallel alerting of multiple devices, and advanced voicemail services. CAMEL has enabled call-unrelated services too, for example, for mobility or messaging [45,46].

3. Continuation of Existing in Services and Replacement Possibilities

Nowadays, we are witnessing rapid changes in telecommunications. Some Communication Service Providers are just introducing Voice over LTE (VoLTE) on an IP Multimedia Subsystem (IMS) architecture besides their existing 2G and/or 3G networks [3,34,47]. Meanwhile, in several countries, the sunset of 2G and/or 3G networks has already started, forcing MNOs to provide end-user services purely on an IMS and to shut down their 2G and/or 3G networks, where previously legacy IN-based services were provided. In both cases the legacy 2G/3G Intelligent Networks services need continuation for subscribers in the IMS domain. Figure 4 shows the IN-based service evolution, reflecting the continuation possibilities of legacy IN-based services, and the replacement possibilities to enable the ramp-down of the service control point (SCP) network elements.

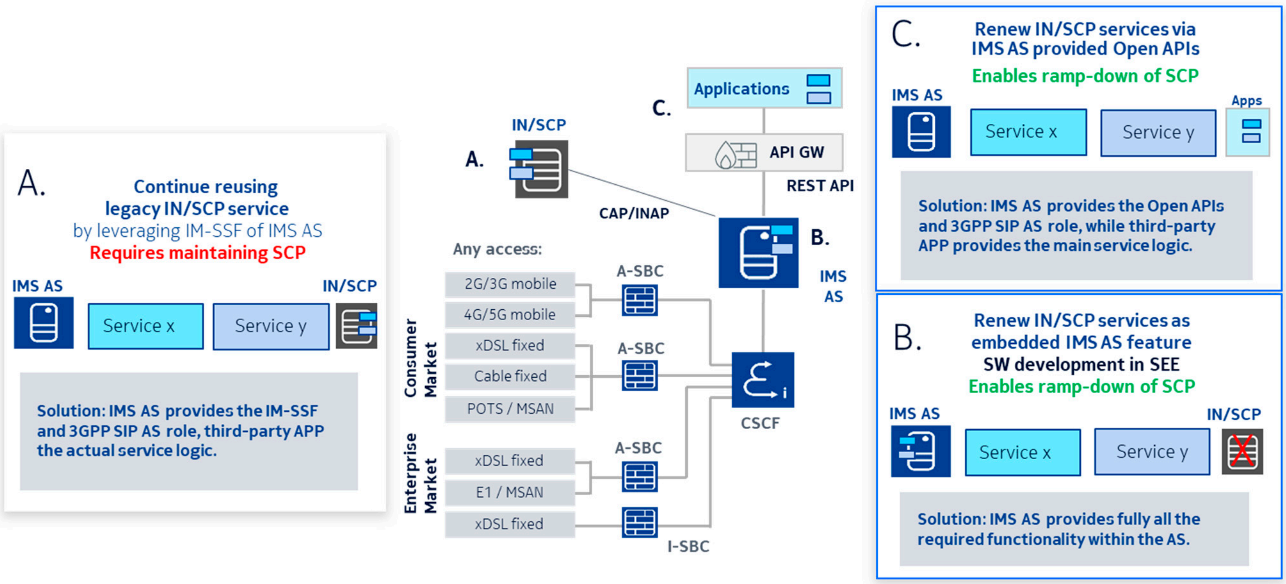

Figure 4. Alternatives to provide CS domain services in the IMS domain (**A**: continue with the existing IN service, **B**: implement the service natively as an IMS AS, **C**: invoke the service over API).

3.1. CAP/INAP-Based Service Invocation

The seamless continuation of CAP/INAP services for IMS subscribers can be enabled by the IM-SSF role of the IMS Application Server (IMS AS), which can even be integrated with the MMTEL/SCC AS (Multimedia Telephony/Service Centralization and Continuity Application Server) roles (Figure 5) [47–49]. Since IMS anchoring of the subscribers is optional during the call, IN services can be invoked from the 2G/3G domain as well.

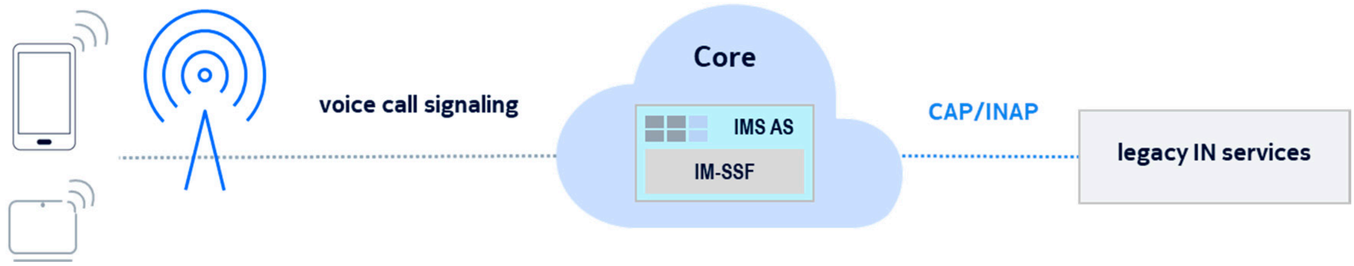

Figure 5. Traditional IN-based services executed by the IM-SSF.

There are some drawbacks of this solution, as follows:

- This approach requires the maintenance of the IN platform, and the service development needs telecommunication (SS7) experts. These products are mature and may be even close to the end of their life cycle;
- Although 3GPP has specified the IP Multimedia Service Switching Function (IM-SSF), it is not delivered by all IMS core vendors. Therefore, continuation of existing IN services has become very challenging in many MNO networks;
- CAP/INAP services tend to follow the standard protocol specifications strictly; introducing protocol extensions may lead to incompatibility.

3.2. SIP-Based Service Invocation

There are IN vendors where the service logic can be invoked on its legacy CAP/INAP interfaces from the 2G/3G domain, while it can also be invoked on a SIP-based (Session Initiation Protocol) interface from the IMS domain. It requires both maintenance of the existing IN and development of the SIP-based service invocation.

Alternatively, IMS AS vendors may decide to implement replacement services. Typically, such implementations are integrated to MMTEL AS in order to enable strong MMTEL interworking, assuming a microservice architecture. For example, an integrated MMTEL/SCC AS may provide parallel alerting of multiple devices with a single subscription, with shared MMTEL data for all devices and their terminating SIP sessions controlled by IN services. Furthermore, an IMS native Selective Ringback Tone service may allow the calling party to hear a customized ringback tone while the called party is alerted. That is, instead of the existing ringback tone, the calling party hears a melody or a greeting specified by the called party while waiting for the receiver to respond to the call. The called party can select a melody or greeting based on the identity of the calling party.

3.3. API-Based Service Invocation

The API (Application Programming Interface) is a way for two (or more) computer programs to communicate with each other. The API can be considered also as a type of SW interface, offering service(s) to other pieces of SW. As overviewed in the next section, APIs have been already used widespread for a long time in telecommunication networks. First, APIs have been mainly used for internal CSP purposes, for example, to integrate customer relationship management into charging procedures. Integrating the Information Technology platform resources to the telecommunication (simply 'Telco') platform of the CSP has become another typical use case. The use of APIs has improved operational efficiency and reduced OpEx (Operational Expenditure) [17].

APIs in an IMS AS may be also a valid alternative for IN replacement. In this approach, a standalone IMS AS or an MMTEL AS may expose network functions to API-based services, which again can decouple service logic from the IMS, enabling a shorter time to market. Up to now, the fusion of IT and Telco domains has been very challenging because they required different technologies and different platforms, and traditionally they had a different developer base. If Telco networks start using APIs instead of legacy Telco signaling-based services, then a similar platform can host both Telco and IT services [17,50]. To conclude, APIs can be used not only for IN replacement, but APIs also enable fusion of services in the Telco and IT domains.

4. Fusion of Telco and IT Services

4.1. Evolution Path of API Services in Telecommunications

A brief overview of Application Programming Interface-based services is given in this section by reviewing several papers. The selected papers cover the evolution path of APIs over several years. In the same timeframe, the telecommunication landscape has been evolving too, starting from legacy 2G/3G to actual 4G/5G and future 6G mobile systems. In an early paper, dating back to 2001, the authors discussed the possibility of using Open APIs for mobile networks [51]. In those years, content distribution to mobile terminals became available through the increased data rates offered by EDGE and WCDMA (Wideband Code Division Multiple Access) technology [3]. One mobile network vendor (Ericsson) provided a platform that enabled OEM (Original Equipment Manufacturer) vendors to develop applications and graphical user interfaces on top of their platform. This way, mobile phone terminal manufacturers gained the possibility to differentiate their products from other vendors.

In 2003, Lozinski [52] provided an overview of the Parlay/OSA (Open Services Architecture) API, an open interface that was created by a consortium of 65 IT and telecom industry companies. Parlay/OSA APIs have been used to develop services for both mobile data and fixed networks. Furthermore, the APIs targeted services for the next-generation converged networks based on the Internet Protocol (IP), as expected at that time. Among others, the main advantages have been using technology-independent APIs built on open standards. Developers could use multiple programming languages (e.g., C, C++, or Java). New value-added services became available, which promised revenue for MNOs and CSPs. Various domains were targeted by the new services, e.g., mobile location, terminal capability, connection management, and charging.

In 2008, it was shown by [53] how the convergence of traditional telephone networks with the Internet started benefiting from the convenient user interface and relatively big storage size of personal computers, which the usual telephone devices did not have at that time. SOAP- and REST (Representational State Transfer)-based APIs were shown in that paper for building call and messaging services in which callers could control their own calls. It was shown that REST is a good alternative to SOAP when developing Open APIs. Several services are detailed, such as third-party invitations for mini-conferencing, click to dial, call recording, short and voice messaging, and playing audio on demand during a call.

Yrjo and Rushil discussed already in 2011 how cloud computing and IT created new possibilities towards 'Open Telco' by changing the legacy telecommunication landscape [12]. Their paper underlined the importance of Open APIs in this evolution. Two steps are discussed: how operators can consider Open Telco and Networking as a Service (NaaS) concepts. On the one hand, network operators could use Open APIs to provide network assets to developers for accelerating application development and creating a new application ecosystem. On the other hand, operators could start to use all kinds of cloud computing services in their own infrastructure, including Infrastructure (IaaS), Platform (PaaS) and Software as a Service (SaaS). The IaaS layer offers networking, computation, and storage services provided by the cloud. The PaaS layer has close links to Business and Operations Support Systems (BSS/OSS). The SaaS layer matches the service delivery platforms.

In another paper dating back to 2011, Liu et al. [34] concluded that the opening and sharing of Internet and telecom services was a must to satisfy subscribers. The authors stated that according to the long tail theory, 20% of the telecom services satisfied 80% of the subscribers. However, subscribers' demands were not fully aligned with the operators' services. To overcome these limitations, IMS could provide multimedia services over Internet Protocol (using REST APIs or RPC-based methods, e.g., SOAP). Even though IMS and Internet services have several common features, they differ in some fundamental points, such as access control or business models. To expose telecom abilities to the Internet world, the Telco TM Initiative was born with the emergence of the web. Telco 2.0 offered new telecom business models, and WIMS 2.0 (Web 2.0 & IMS) was proposed as a solution to enable convergence between the mobile world and the web. The exposure of IMS capabilities to the outer world was by Open Web APIs, as described in that paper.

In article [1], the authors presented a set of APIs used as part of machine-to-machine communication as a REST-based web service. With the help of these APIs, e.g., it was possible to send SMS/e-mail/Twitter messages to devices registered in the M2M network, showing the early convergence of Telco and IT services already in 2012. As specific use cases, the authors mentioned smart home applications, whereby the subscribers received notifications on their phones about the temperature and light conditions in their homes or when an unauthorized person was intruding, based on inputs from motion sensors.

In 2015, Grabowski et al. [54] reported on two Hackathon events, where new telecommunication-related applications were implemented using a set of Open APIs, combined with datasets provided by Open Data APIs. With the help of APIs provided by a mobile network operator, it was possible to send and receive SMS, MMS, and USSD (Unstructured Supplementary Service Data) notifications, initiate calls, and manage location-, charging-, and SIM card-related data as a REST web service. In addition, detailed maps of several cities (including public transport networks and major institutions, such as hospitals, etc.) could be accessed via an Open Data API. At these two events, an impressive number of more than 100 applications was developed, which also demonstrated the attractiveness of telecommunications services. The Hackathon organizers measured thousands of API calls during the use of the developed applications. The authors also concluded that it is very beneficial to work with interdisciplinary teams during API development, in such a way combining the knowledge of telecommunications and, e.g., the real estate market.

In 2019, the authors of [55] outlined a testing framework used for 5G performance and use case testing purposes. In the 5G-VINNI project, it was important to utilize the Open API to access certain elements in the network infrastructure, and this method was also recommended to manage the life cycle of network slices. The project mentioned specific APIs discussed in later articles [56,57].

According to [8,17,58], the Open API concept plays an important role in 5G core networks. The services of different new user groups (called verticals) can be integrated into mobile networks with standard RESTful API calls via the Northbound Interface provided by the Network Exposure Function (NEF). The authors of [4] outlined that the efficient programmability and dynamic shaping of 5G and 6G networks (e.g., management of network slices) are also possible with the invocation of API services, emphasizing the principles of a Software-Defined Network and Network Function Virtualization (NFV).

A recent paper from 2021 focused on the security aspect of 5G core networks, emphasizing that the APIs themselves must be protected [59]. This is primarily true in relation to Network Exposure Function, where it is necessary to consider the level of accessibility to the operator's network provided to a third-party through an API [8,17]. Access has three levels: passive, semi-active, and fully active. At the fully active level, the API developer is authorized to install new network elements within the given network slices. The article also discussed the security risks related to Network Virtualization and Edge Computing; in the latter, the Multi-Access Edge Computing (MEC) cloud-based IT service can also use the Open API, and the authors warn that security risks must also be avoided at the edge of the network [59–61]. API security considerations are also crucial in mobile banking applications, whose services are more and more widespread worldwide [31].

In 2022, Kao and Young [6] noted that every generation of wireless systems has its own representative industries and companies. Network equipment vendors and operators were at center stage in the 1G era. Feature phones and the corresponding supply chains like Qualcomm and Nokia became dominant in the 2G era. Smartphones and their suppliers like Apple started to rise in the 3G era. And the OTT applications riding the mobile network reaped most benefit in the 4G era. Currently in the 5G era, there are also numerous opportunities open for new players. In general, 5G introduces many IT technologies, and that helps openness and network disaggregation for preventing vendor lock-in (i.e., locking in one vendor's proprietary solutions). In this way, more players can join the supply chain to increase flexibility and diversification. More specifically, 5G involves the combination of Communication Technology, IT (Information Technology) and OT (Operation Technology). Therefore, in addition to the communication network itself, plus all possible new applications, 5G brings many new industry opportunities [2–6]. The industrial cooperation aspects of Open APIs have been discussed for years [8,48]. Simultaneously, there has been a significant focus on standardization issues too [1,16,62–64].

The reviewed papers are summarized in Table 1. As shown, the selected API related papers cover various domains of IT and telecommunications. The most intensively discussed topics within the list of the reviewed papers are 4G, 5G, and cloud core. IT and Telco convergence is clearly observed. Notably, in the majority of the papers, various new business models, resource management issues, and security and standardization aspects received significant focus too.

Table 1. The various Telco and IT areas discussed in the reviewed works.

Telco and IT Domains	References
2G, GSM	[2,3,6–8,10,11,33–35,45–48,51–54]
3G, UMTS	[2,3,6–8,10,11,14,17,22,33–35,45–54,59]
4G, LTE	[2–12,14,17,20,22,23,32,33,35,47,49,50,56,59,61,62,65–67]
5G, NR	[2–12,14,15,17,19,22–28,32,35,55–61,63,66–68]
6G	[3,4,12,24,61,63]
Open RAN	[6,8,9,61]
SDN	[2,8,13–15,19,22–25,55,57,61]
M2M, IoT	[1,2,4,5,12,15,17,24,32,55,59,61,63]
IMS, core network	[1–3,8,10,11,14,17–19,21,23,27,28,33–35,45–49,58,59,61,62,65–69]
Cloud, VNF, CNF	[2,3,5,8,10,11,16–18,20–26,28–30,33–35,55–61,63,65,67]
Resource management, scaling, slicing	[2,4,8,11,16–18,20–22,24–27,29,30,56–58]
Security	[2,5,8,10,11,14,15,17,22,27,31,55,57,59,61,63]
IN, INAP, CAMEL	[7,10,11,20,23,45,46,48,52,53,63,64]
Parlay / OSA, SOAP	[10,11,16,23,34,45,46,52–54,62–64,67]
API, REST API, Open API	[1,4,9–12,14–17,20,24,25,30,31,34,35,50–59,61,63–67]
Data Channel (DC)	[49,65–69]
Standards, standardization	[2,7–11,22,31,36–44,48,49,54–56,59,61–69]
(New) business models, opportunities	[2,4–6,8,16,19,20,22,28,31,32,51,52,54,55,64,65]

4.2. Nokia TAS Open APIs

A robust, easy to use set of APIs is the key to unlocking innovation and exciting developers. Nokia's API-enabled 5G core product functions can be exposed securely to the public domain over the Nokia Network Exposure Function (NEF), which also acts as the API Gateway. The Nokia Telephony Application Server (NTAS) provides OMA-based RESTful Network Open APIs as future-proof functionality. The API-based solution of Nokia TAS can be seen in Figure 6.

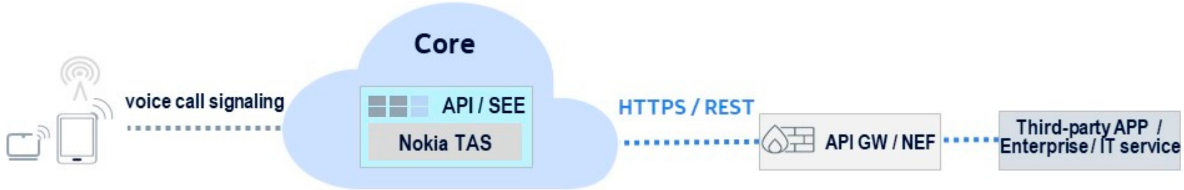

Figure 6. Application programming interface-based solution in Nokia Telephony Application Server.

The API functionality is enabled for 2G, 3G, 4G, 5G, VoWiFi, and fixed networks; hence, it is seamlessly available for operators with Fixed–Mobile Convergence efforts. It is also the key enabler of the Telco-IT fusion, as can be seen in Figure 7.

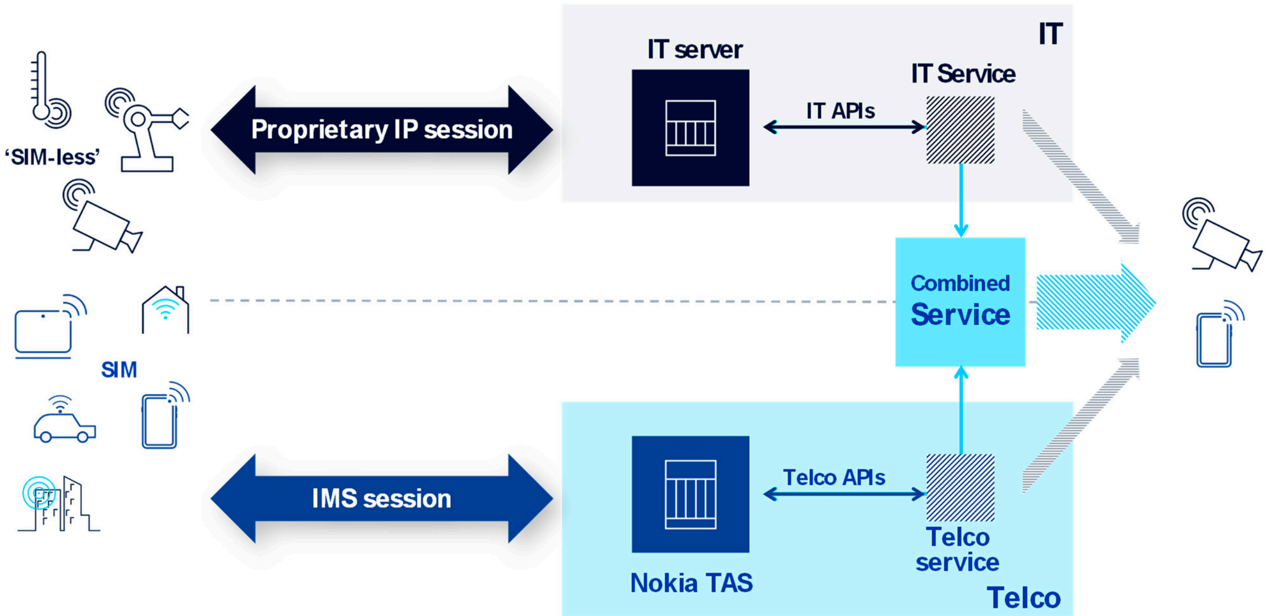

Figure 7. Fusion of IT and telco worlds.

Benefits of the API Framework

With their solution principles, the API-based services provide benefits, such as the following:

- Faster time to market is possible for complex services compared to the traditional approaches; quick development is feasible with a large third-party developer base, using feature-rich APIs and libraries (they also unlock the Internet of Things and social media);
- Opening the IT domain for Telco can allow IMS services to become more sophisticated. The services are delivered with orchestrated service execution in a cloud-native fashion; serverless technologies and service mesh mode are also feasible;
- The 3GPP IMS AS interworking is ensured on Southbound Interfaces;
- A rich catalog of Open and RESTful Northbound Interfaces is available. For instance, the Nokia TAS has detailed Open API Swagger Documentation for third-party developers. Swagger is also used by 3GPP to describe the 5G interfaces. The Swagger definition text file describes the complete interface. Both sides of the interfaces can be tested easily based on the Swagger definition. Public testing tools for functional and load tests are available, and it enables collaborative API design (via GitHub). Automatic documentation and code generation are also possible. All in all, this API yields lower efforts for the operators and Nokia as well;
- The OpEx saving is also important with software reuse, including lower maintenance costs [17].

4.3. Nokia TAS Open API Use Cases

With the usage of Telco APIs, the traditional telecommunication service domain can easily be enriched with IT API-based services, as shown in Figure 8.

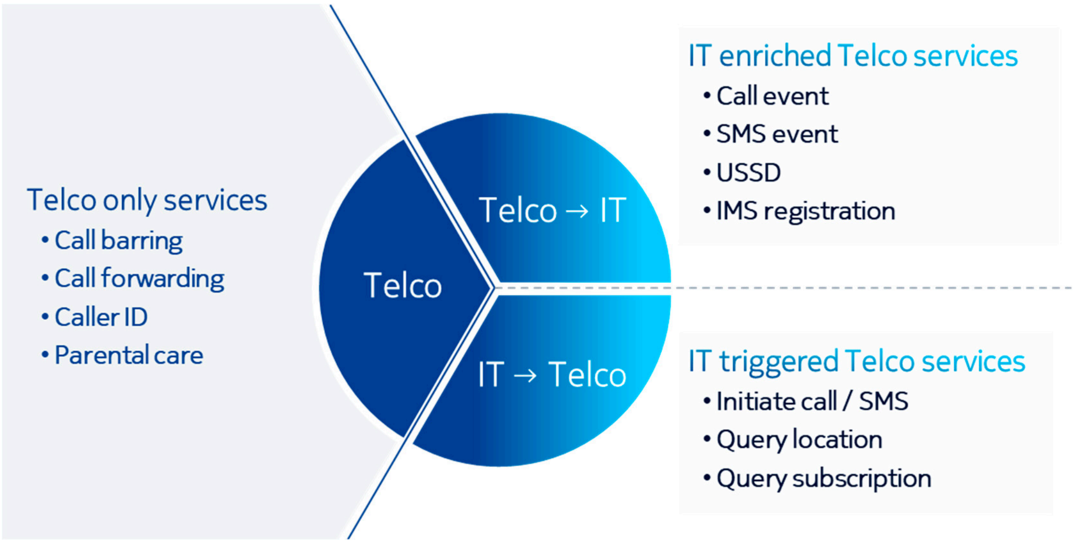

Figure 8. Use cases after IT–Telco fusions.

Besides the examples shown in Figure 8, hereby some examples are listed of what kind of possibilities are provided for the operators utilizing various APIs (when changing from Telco-only services):

- Call Direction API: This suspends the call and triggers the application to take the appropriate route decision or change the calling line ID. The operator can develop applications such as the following:
  - Nuisance call blocking, which recognizes and blocks robocalls or telemarketing calls in the network according to call blocking application settings;
  - Blocking all calls to children during school time;
  - Mashing up connected car data to change the calling pattern while driving (i.e., call blocking with a personal exception list);
  - Calendar-based call forwarding that extends end users' reachability conditions with a personal/office calendar application (e.g., Google Calendar);
  - Caller ID enrichment with the name of the calling party, which can enable companies to reach out to their customers with an increased success rate;
  - Posting automatic social media advertisements by the application for personal benefits (e.g., when user calls a restaurant for booking, the API service can advertise the restaurant on a personal Facebook page in return for a discount);
  - Temporary call ID that enables two parties to call each other without sharing their personal phone numbers and therefore increases communication privacy;
  - Basic parental/elder care is also possible by notifying parents/caregivers about calls from children/older people.
- Call Event Notification API: This notifies call events without having the possibility of influencing the call. The operators may develop services like the following:
  - Integration with Over-the-Top (OTT) phone applications; for example, based on the network notification of an incoming call, the service may send a push notification to the OTT application that can include the user's previous personal notes on the caller;
  - It can also help to build a smart home: e.g., blinking a lamp could notify the subscriber about incoming calls;

    - Notification of missed calls to IT/social media services (e.g., callback reminder to Google Calendar or a Twitter personal message) to increase the notification space of the end user;
    - Building a personal server-based call history database that can be accessed on a web portal.
- Call Control API: Third-party call control functions, which can initiate a call and manage call participants (e.g., add or drop participants), such as the following:
    - Service center call management: monitoring of agent availabilities and providing customer callback when an agent becomes available for a call;
    - Ordered call conference: A service initiated or a scheduled call conference between two or more parties.
- SMS API: This sends an SMS to a user and notifies service logic on a received SMS, including the following:
    - Two-factor authentication with SMS;
    - SMS notification of a missed incoming call;
    - SMS televoting;
    - SMS chatbot (ChatGPT [70] service reservation and support center);
    - SMS-based advertisement.

4.4. IMS Data Channel

The 3GPP has recently introduced a new concept that enables the usage of a data channel in IMS (IP Multimedia Subsystem) call sessions to enrich the end user call experience [49]. It enhances the native dialer application of mobile devices with browser capabilities, which could receive HTML and JavaScript content over the IMS Data Channel, which is yet another channel/media type besides regular voice and video. It allows MNOs to provide in-call web applications without the need to install OTT apps from the Google Play Store or the Apple App Store. An IMS Data Channel (DC) can be established between the device and the network, between the device and an application server, or between devices, and can be used for sending or receiving any kind of data (for example the HTML page itself, Augmented Reality- or Virtual Reality-related data, database queries, or content sharing). Different applications may have different bandwidth requirements; therefore, the guaranteed bandwidth of an IMS Data Channel may be controlled by the network.

Like API-based services, IMS Data Channel applications may also be easily integrated with IT services. However, they provide different services. API-based services are more telecommunications-oriented: At certain call events, they can affect routing and charging, and they may implement interaction with the end user using network announcements. On the other hand, an IMS Data Channel extends the phone capabilities with a browser that can deliver interactive solutions to the end user during calls without any effect on the routing or charging but opening the door towards augmented communication [65–69]. Therefore API-based services are device-agnostic, while an IMS Data Channel requires special capabilities from the device(s).

The GSMA proposes an initial list of use cases, which can be extended with even more exciting ones [66,67], including the following:

- A visual menu for the support center;
- Call queue information;
- An interactive catalog;
- Content sharing;
- Online gaming;
- Personalized targeted advertisements;
- Real-time speech transcription and translation [35].

5. Conclusions

Telecommunication networks have gone through a drastic evolution whereby the business logic and the service logic have been separated, as we can see through the Nokia TAS API service examples. The originally developed INAP and CAMEL services are reaching their end of life and are being replaced with native services implemented as an IMS AS or with API-based services. Moreover, the IN replacement, API-based services, also enable faster time to market thanks to a bigger developer base, and the non-Telco-specific service environment unlocks the possibility of easily integrating the Telco and IT domains. However, future trends are moving to device- and access-agnostic directions, where services are orchestrated as shown in Figure 9. Future services may be connected to IT/IoT services and are getting more and more interactive, as we illustrated with IMS DC-related examples.

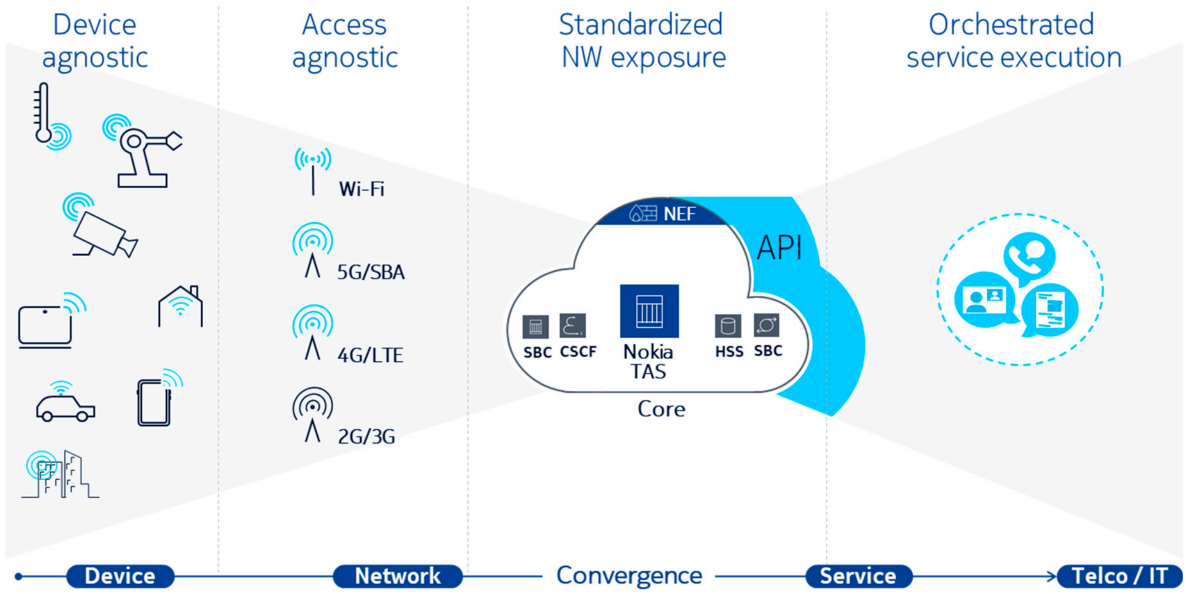

Figure 9. Convergence of telco services.

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Abbreviations

API	Application Programming Interface
AS	Application Server
ATM	Asynchronous Transfer Mode
BL	Business Logic
BTS	Base Transceiver Station
CAMEL	Customized Applications for Mobile network Enhanced Logic
CAP	CAMEL Application Part

CNF	Cloud-native Network Function
CS	Circuit Switched
CSCF	Call Session Control Function
CSP	Communication Service Provider
CP	Control Plane
DC	Data Channel
EDGE	Enhanced Data rates for GSM Evolution
EPC	Evolved Packet Core
ETSI	European Telecommunications Standards Institute
FMC	Fixed–Mobile Convergence
GSM	Global System for Mobile Communications
HLR	Home Location Register
HSS	Home Subscriber Server
HW	hardware
IaaS	Infrastructure as a Service
IMS	IP Multimedia Subsystem
IN	Intelligent Network
INAP	Intelligent Network Application Protocol
IM-SSF	IP Multimedia Service Switching Function
IP	Internet Protocol
IT	Information Technology
IoT	Internet of Things
LTE	Long-Term Evolution
LTE-A	Advanced LTE
MEC	Multi-Access Edge Computing
MNO	Mobile Network Operator
MMS	Multimedia Messaging Service
MMTEL	Multimedia Telephony
MSC	Mobile Switching Center
MSS	MSC Server
M2M	Machine-to-Machine
NaaS	Networking as a Service
NE	Network Element
NR	New Radio
NSS	Network Switching Subsystem
NW	network
OEM	Original Equipment Manufacturer
OMA	Open Mobile Alliance
OpEx	Operational Expenditure
OSA	Open Services Architecture
OT	Operation Technology
OTT	Over-the-Top
PaaS	Platform as a Service
PDH	Plesiochronous Digital Hierarchy
POTS	Plain Old Telephone Service
PNF	Physical Network Function
PS	Packet Switched
PSTN	Public Switched Telephone Networks
REST	Representational State Transfer
RAN	Radio Access Network
RAT	Radio Access Technology
SaaS	Software as a Service
SBA	Service-Based Architecture
SBC	Session Border Controller
SCC AS	Service Centralization and Continuity Application Server
SCF	Service Control Function
SCP	Service Control Point

SDF	Service Data Function
SDH	Synchronous Digital Hierarchy
SDN	Software-Defined Network
SEE	Service Execution Environment
SIP	Session Initiation Protocol
SL	Service Logic
SMF	Service Management Function
SMS	Short Message Services
SMSC	SMS Center
SS7	Signaling System No.7
SW	software
TAS	Telephony (or Telecommunications) Application Server
TDM	Time-Division Multiplexing
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
UP	User Plane
USSD	Unstructured Supplementary Service Data
VNF	Virtualized Network Function
VoIP	Voice over IP
VoLTE	Voice over LTE
VoWiFi	Voice over WiFi
WCDMA	Wideband Code Division Multiple Access
WiFi	Wireless Fidelity
1G	First-Generation (early analog mobile systems)
2G	Second-Generation (mobile systems), also known as GSM
2.5G	2G systems with EDGE
3G	Third Generation (mobile systems), also known as UMTS
3GPP	Third-Generation Partnership Project
4G	Fourth Generation (mobile systems), also known as LTE
5G	Fifth Generation (mobile systems), also known as NR
6G	Sixth Generation (mobile systems)

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