The Potential Cyber and Network Security Issues of PSTN Closure

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Abstract — Up until a few years ago, all phone calls over land lines, mobile networks, cable TV networks and many altnets used circuit-switching technology. This has been the case despite the massive build-up of packet-based data networks – and the dominance of Wi-Fi, broadband, and the Internet in people's lives over the last 20 years or so. Now all these network operators are engaged in shifting telephone service onto their packet-based data infrastructures and withdrawing the obsolescent circuit switched technology. This article considers why this change is happening, how calls will be handled in the future and the big challenges faced by landline operators in this transition, with special emphasize on the potential cyber and network security issues involved.

Keywords — all-IP NGN, IP phone, PTSN, VoIP

1. The End of an Era

Since its introduction in the late 1800s the switching of landline telephone calls within the public switched telephone networks (PSTN) has relied on a succession of systems based on the best technologies of the day. Figure 1 shows a stylized view of the types of technology that have come and gone over the last century Given the often-lengthy transition periods as old systems are replaced by the new, invariably at any one time there will be a mix of different technologies in a PSTN. Despite this, network operators have provided continuity of service, upgrading exchange systems with little or no breaks over the years. Up until recently all telephone switching systems – originally manual then automatic analogue and now digital time-division multiplexed (TDM) electronic type equipment – have been circuit switched, providing "connection-orientated" continuous bi-directional paths between calling and called subscribers for the duration of the call [1].

Now, PSTNs around the world are currently moving into the new era of "connectionless" digital packet switching for telephony. Unlike the existing digital TDM systems which are synchronous, digital packet systems are asynchronous. In this context, synchronous means that the encoded voice bits – conveying speech and silence – are continuously transmitted and switched in both directions within the circuit under the control of regular clock pulses. Asynchronous means that encoded voice bits are grouped into appropriate packets and forwarded through the network routers on an as-and-when basis. The packet approach has the important advantage that the voice packets can be easily interlaced with data packets

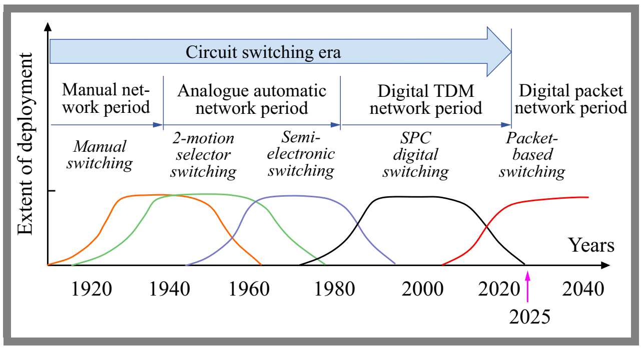

Fig. 1. Telephone switching technology life cycles.

on the same highway, so creating an integrated voice-data network (or multi-service platform). However, the asynchrony also means that packets can experience variable delay across the networks which can lead to impairment of the speech quality. The likelihood of such problems being perceived by the listeners is minimized by appropriate dimensioning of network capacity and giving higher priority to voice packets.

2. Why Change?

Stored-program-controlled (SPC) digital switching systems were introduced into PSTNs around the World during the 1980s. Notable examples include the US ESS, the Japanese NEAX, the German EWSD, the French System-12, the Canadian DMS100, the Swedish AXE10, and the British System-X. By the turn of the century, most of these systems were reaching the end of their economic life. Although generally still working well, manufacturers progressively began to reduce their support, so availability of spare parts and software upgrades became a problem for network operators. It was clear that replacements would be needed eventually, but the big question was what technology should be used to replace these exchanges?

The telecommunication environment had changed considerably since the SPC digital circuit switches were first introduced given the huge rise in digital data traffic generated by both businesses and consumers. Known in the industry as the "data wave", it was estimated that in the UK, the number of bits carrying data exceeded that of digital pulse-code modulation (PCM) encoded voice around 2005 for the fixed network, and 2010 for mobile networks. Equally important, packet-based network equipment was expanding beyond enterprise

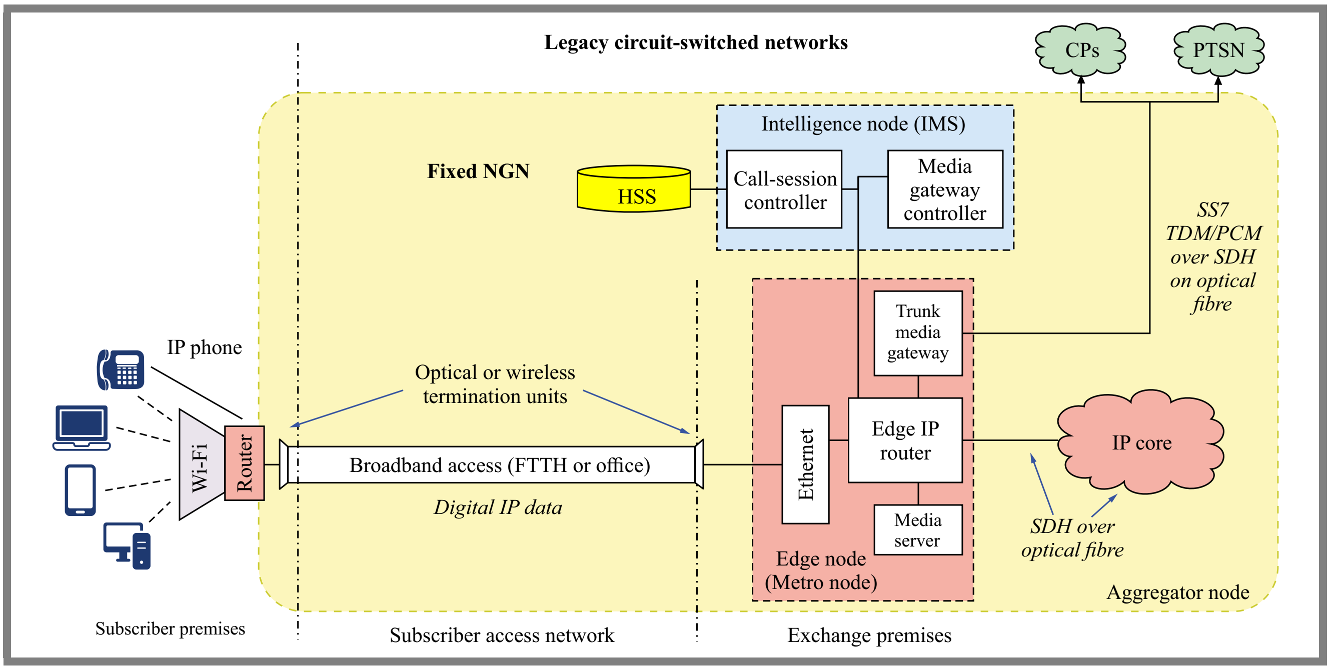

Fig. 2. Generalized view of an NGN replacement of PSTN exchanges.

networks and becoming a credible alternative to the existing equipment used in the PSTN and public data networks (i.e., carrier grade). This led to the International Telecommunications Union (ITU) in 2006 defining the concept of the Next generation network (NGN), which characterized the features of future networks that would not only replace the PSTNs but also form a common platform for an operator's mobile and data networks. [2] They also identified the possible scenarios for transforming the existing PSTN to an NGN, which are considered later.

The key characteristics of an NGN are an Internet protocol (IP) platform which supports voice and data services with both fixed and mobile access to the customers. This means that the telephony service currently on the PSTN will be handled as voice-over IP (VoIP) instead of being circuit-switched, and the signaling throughout the network would be session initiation protocol (SIP) instead of signaling system No. 7 (SS7). An important difference between the VoIP and data services provided by an operator's NGN and similar services currently carried over the Internet (e.g., over-the-top applications such as WhatsApp) is that the NGN is a managed platform in which appropriate quality for the various voice and non-voice services can be maintained. As well as providing a viable replacement for the PSTN, the industry expected that the use of multi-service IP platforms would enable new multimedia services, combining digital data, voice, and vison. The expectation was that by moving services onto a common IP platform the operator's many service-specific networks can be closed, giving operational cost savings due to having to operate just one network.

The internationally agreed ITU recommendations on NGNs gave the industry – operators and manufacturers – a defined target to replace the PSTNs. However, it has taken many years for the IP-based equipment to become sufficiently carrier grade to cope with the scale and complexities of the PSTN, with its wide range of users' access lines, services other than telephony, business, and residential users' terminals, etc. In addition, local circumstances, different levels of telecom market competition, national regulation and government policies have influenced the rate of adoption of the NGN concept in each country. Finally, making a credible business case for the huge investment required to replace the PSTN has proved be a big challenge. However, from around 2010 onwards operators have embarked on making the transition to an NGN.

Of course, in many countries there are several operators providing telephone service: the incumbent operator and a few alternate operators, including some cable TV companies. Many of the alternate operators have their own circuit-switched PSTN. Interestingly, around the world the programs of withdrawing the PSTNs have been publicized using a variety of names – "PSTN sunset" or "POTS switch-off" in the USA, "End of the PSTN" in France, part of the "National Broadband Network" rollout in Australia, "All-IP transformation" in Germany, and "The move to all-IP" in the UK.

3. What does the Replacement for the PSTN Exchange Look like?

The NGN replacement for the PSTN has a completely different architecture. There is no one-for-one replacement of the circuit digital TDM switch-blocks. Instead, packetized voice is carried through a data Core Network of IP routers through to the destination subscriber's line under the control of multiple intelligence nodes, usually dispersed across the network. The call is set up through the router network using a sequence of

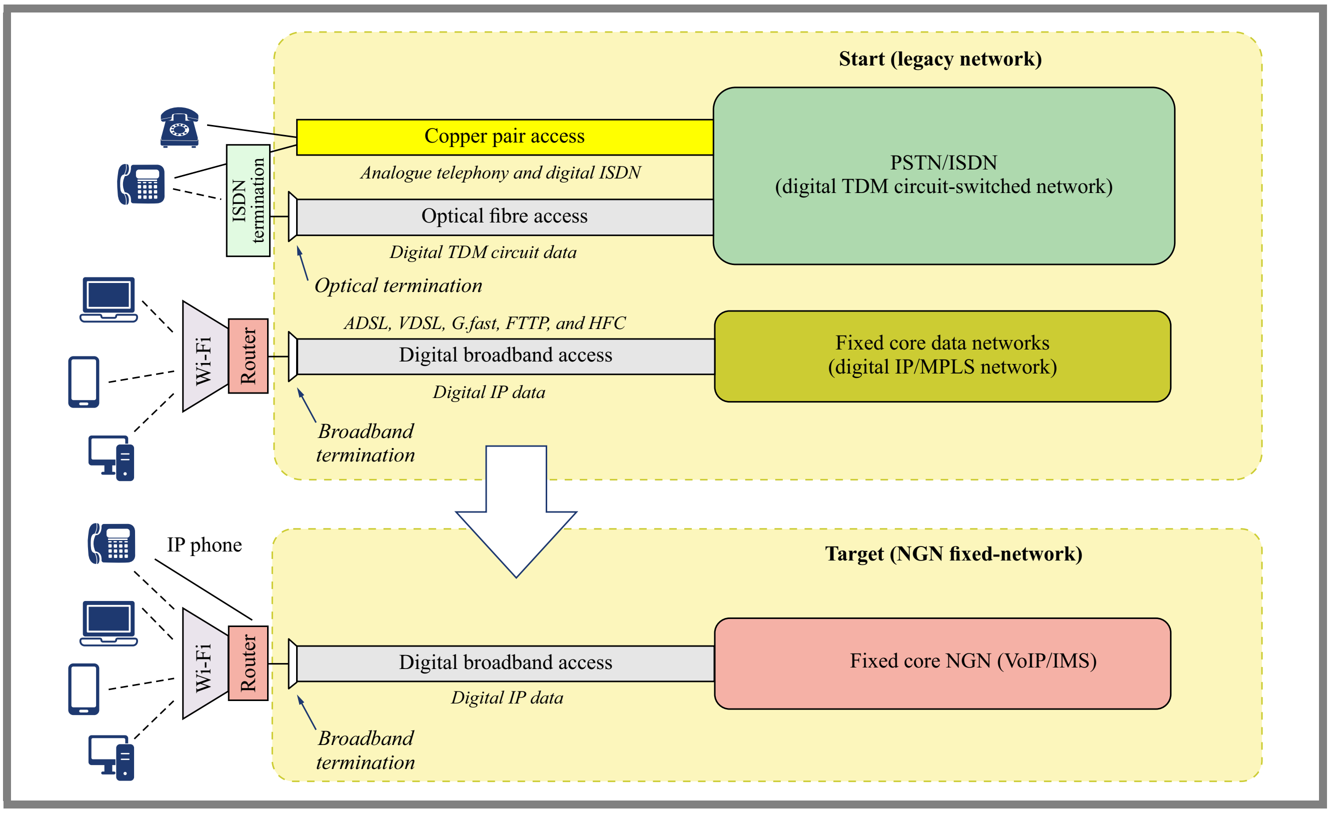

Fig. 3. Generalized view of the transition to all-IP NGN.

SIP messages. Ringing tone is inserted into the audio channel at the called subscriber node, to give users reassurance that the call has succeeded.

A simple schematic diagram of an NGN network is shown in Fig. 2. It is assumed that the subscribers' telephones, whether business or residential, are IP (VoIP) phones, with voice codec, conversion to/from IP packets and SIP signaling within the instrument. The IP phone is connected to the access broadband line system either directly or via Wi-Fi. At the exchange building the broadband line system is linked to an Ethernet switch or an edge router, which provides the classic edge network function of traffic aggregation.

Voice packets are routed through the operator's IP network interlaced with the various non-voice data packets. The control of the telephony service is provided by the call-session control function (CSCF) in an intelligence node, usually remote within the network. Subscriber's profile data, such as telephone numbers, service features, etc., are stored in the home subscriber server (HSS) and there is also a call charging system which supports the "calls" and stores the call records (for simplicity not shown in Fig. 2).

Interestingly, routing is still based on telephone numbers. Therefore, the dialed number first needs to be converted from the recipient's phone number to an appropriate IP address (actually, a universal resource identifier, URI) for insertion into the headers of the sender's voice packet. This conversion generally uses the ENUM algorithm [3] in a domain name system (DNS) within the network (not shown in Fig. 2).

Finally, the trunk media gateway provides an interworking facility between the NGN and remaining circuit-switched (usually known as legacy) networks to which it needs to connect, nationally or internationally. This gateway provides both voice transcoding between IP packets and TDM PCM channels, as well as signaling conversion between SIP and SS7 messages. Where necessary, the interworking may also involve embedding certain service-specific SS7 messages within the SIP IP packets (i.e., embedded ISUP).

It is now generally accepted that the control functions in the intelligent node should adhere to the internationally standardized IP multi-media subsystem (IMS) architecture [4]. This system is specified to facilitate a wide range of IP-based services on fixed and mobile networks. For example, IMS has recently been deployed to enable voice switching on 4G mobile networks – i.e., voice on LTE (VoLTE). Although capable of supporting many types of multi-media (voice, data, and video) services, the biggest current application is still telephony. By making IMS part of the NGN replacement for the (fixed) PSTN, operators can progressively build a unified NGN platform for fixed and mobile access covering voice and data services. This produces platform integration as well as service convergence, as envisaged by the ITU recommendations.

4. The Transition to an All-IP Network

The big challenge facing network operators worldwide has been deciding how to replace large numbers of PSTN ex-

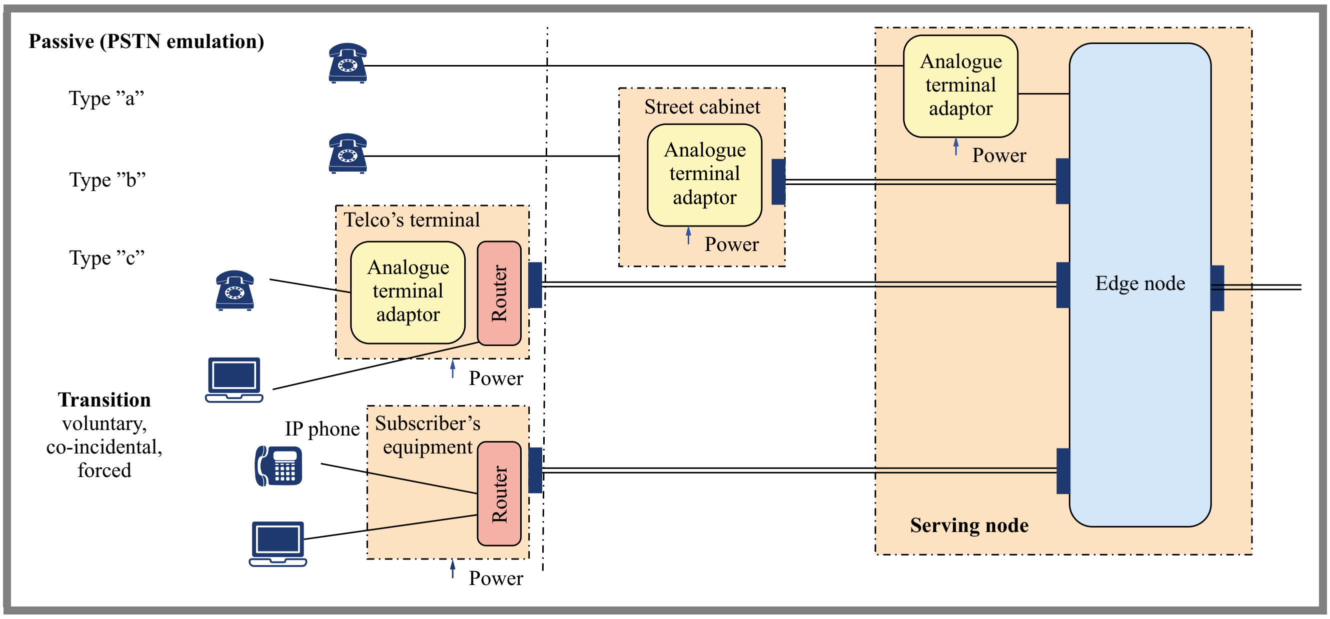

Fig. 4. Possible locations of the analogue terminal adaptor.

changes and move to an NGN, while still maintaining continuity of telephone service during the several years of transition. The problem is complex because there is a wide range of PSTN existing business and residential customer types, ranging from those who are "tech savvy" (i.e., computer literate) with high-speed broadband to customers without any computers, broadband access, or even mobile phones. This complexity is captured in Fig. 3, which shows a generalized view of the typical starting point for a telco and the target network. PSTN customers have their telephone service provided from the local serving exchange over landlines, usually composed of a copper pair. The pair may also support voice and data over ISDN (integrated services digital network), as well as different forms of broadband access (e.g., ADSL) or in a hybrid arrangement with optical fiber (e.g. VDSL and G.Fast). Many business premises will still have their telephony switched on site in a digital ISDN private branch exchanges (ISPBX) and linked to the exchange via primary rate (2 Mbit/s or 1.5 Mbit/s) ISDN typically over optical fiber, often using a mixture of signaling systems. There may also be private circuits or alarm circuits carried over the copper lines and terminating at the exchange MDF (for simplicity not shown in Fig. 3).

The target network is an NGN-type common-services IP platform supporting the data and voice services, as described earlier. Here, the customer's devices on the premises interface to the service hub at the IP level – i.e., IP phones for telephony – directly or via the home Wi-Fi system for transmission over high-speed broadband over optical fiber or microwave radio.

The big question for the operators is how best to manage the mix of customer types during the transition to an all-IP (NGN) target network. Based on the experiences of several countries a set of four categories of migration have been identified [5].

Voluntary: Where a subscriber replaces their analogue telephone instrument with an IP telephone of their own volition. This might be done as a result of an upgrade to IT infrastructure at a business premise or early adoption by a tech-savvy residential customer.

Co-incidental (also known as opportunistic migration): When a subscriber has a FTTP broadband access service installed and the copper line is withdrawn this is inherently a VoIP solution. So, the subscriber is expected to provide an IP phone at the time of fiber installation.

Passive: Where a subscriber keeps their existing analogue telephone and copper line even though the operator transfers line to an all-IP network. In this situation the operator provides a "PSTN emulation" facility to allow the customer to experience normal telephony, and possibly remain unaware of the shift to the all-IP network.

Forced: Where the operator requires the subscriber to replace their analogue phones with an IP phone to continue receiving telephony service. The national regulator is responsible for setting the level of advanced warning for the customers.

Clearly, the main determinant for successful transition is how the introduction of IP phones as replacement for the existing analogues phones is managed. If a customer decides to keep their existing telephones, an analogue-terminal adaptor (ATA) is required somewhere between user and the serving NGN node. This device provides much of the PSTN emulation function to convert analogue speech to digital IP packets. It also provides a SIP-gateway to convert multi-frequency (MF) signaling from the phone's keypad. Finally, the ATA usually provides dial tone and ringing current so giving subscribers a familiar experience when making or receiving a call.

Figure 4 shows the possible locations of the ATA – at the serving NGN edge node, at a street cabinet in the access network or on the customer's premises. The ATA is active equipment which requires constant powering. With the ATA located in the network (cases "a" and "b" in Fig. 4) the customer's operator has to maintain power, otherwise the subscriber is required to provide power (case “c“). There is a consensus that vulnerable people depending on the telephone need a back-up to power their ATA in the event of a break in public power supply. However, countries differ in the national regulator’s requirements and who has responsibility for the providing no-break power supply at the customer’s premises.

Though there is no inherent cost difference between circuit switching and packet switching [6], the latter is cheaper when deployed as a single multi-service platform for both voice and data services, and importantly, the interface costs are shifted to the customer equipment. Therefore, the cost of the ATA (in the PSTN-emulation scenario) is a penalty for the operator – and the transition business case needs to reflect this. Operators around the world have taken different approaches to coping with this issue.

5. What Has Happened So Far?

In 2004 British Telecom announced it was planning to be the first national operator to replace its legacy networks with an NGN – named 21st Century Network (21 CN) [7]. The design was based on replacing the existing local switching units at the serving exchange buildings by 21 CN edge nodes comprising multiple line terminating units, known as multi-service access nodes (MSAN) linked via ethernet to the IP NGN core network. Crucially, the ATA was housed in the MSAN within the exchange building – i.e., PSTN emulation type “a” in Fig. 4. However, following early field trials, BT decided that moving ahead with this approach was too complex for the technology then available and that the 21 CN program would instead concentrate on providing cost-effective broadband access, since the PSTN exchanges were still working well.

This delay resulted in several benefits. The emerging trend for subscribers to become mobile-only households has reduced the number of ATAs required in the new NGN design. With increased numbers of broadband lines, the number of IP phones owned by subscribers also increased (enabling the voluntary approach described above). Of course, the delay of some 10 years also meant that better technology choices were available for a PSTN replacement. BT’s current move to an “all-IP network”, is based on PSTN emulation with the ATA located at the line termination on the sub’s premises, i.e. type “c”.

Interestingly, the independent island territory of Jersey led the move to an NGN with their ambitious program of totally replacing all local copper by optical fiber, together with closure of their PSTN – achieving total conversion by 2018. Their design initially involved a soft-switch-type VoIP exchange replacement, then later moved to an IMS-based NGN approach. The ATA at the at the customer’s premises is provided by the operator Jersey Telecom (JT) – i.e., type“c”. This approach enabled a common design of integrated IP router and ATA to be deployed at every household irrespective of the type of phone, giving economies of scale in equipment costs and simpler installation processes.

Deutsche Telekom (DT) began their German PSTN transformation program in 2014 having had experience of converting their smaller networks in seven other European countries, particularly Croatia and Slovakia. Their policy was that existing broadband data customers were required to provide an ATA with their router on the premises. However, PSTN emulation was provided to telephony-only subscribers, using MSAN in the serving network node – i.e., type “a”. The conversion was substantially completed in 2019, following some important technical upgrades to the program including introduction of IMS and the move to type “c” location of the ATA. In 2020, DT announced that they would be introducing a next-generation IMS platform with network function virtualization with the aim of the “cloudification of voice telephony” using data centers across Germany [8].

Many other countries are following similar approaches in their transformation to all-IP, including Switzerland (completed in 2019) and New Zealand (due to complete in 2022). In contrast to most countries who provide PSTN emulation to support existing analogue voice phones, France is requiring all users to provide an IP phone at the time of conversion. However, the transition period is longer, and subscribers are being given plenty of time to prepare. The target date is 2030 for all operators in France.

It seems that in all cases, the operators are converting their networks on a region-by-region basis, with localized publicity and deployment of installers tightly focused. There are differences in the requirements of the national regulators concerning who should bear the various costs of conversion – for end users and interconnections between operators – as well as the provision of back-up battery powering for vulnerable customers.

Table 1 presents a brief summary of the different rates of progress towards PSTN closure in a range of countries.

6. Cyber and Network Security Issues

Now, to consider the cyber and network security issues of moving the PSTN traffic onto an operator’s IP core network, so that telephony is now mixed with all forms of data – latency tolerant and latency intolerant – including video. So, as Fig. 3 illustrates after closure of the PSTN the voice traffic, which enjoyed the protection of the essentially separate PSTN (walled garden of digital circuit switching, SS7 signaling, and dedicated capacity), is thrown onto the common IP platform. Given the headline in a major UK newspaper this September which said: “BT identifying 2,000 signals a second (on their IP core network) indicate cyber-attacks”[1] questions about the wisdom of this move may need to be asked.

A further recent development for the mobile digital IP core is the opening of the network resources to third-parties through a set of APIs. The GSMA launched the Open Gateway initiative at the Mobile World Conference (MWC) 2023. This has the support of 21 global network operators and was the major theme of MWC 2024. Primarily specified for application de-

[1] Guardian newspaper, 13th September 2024

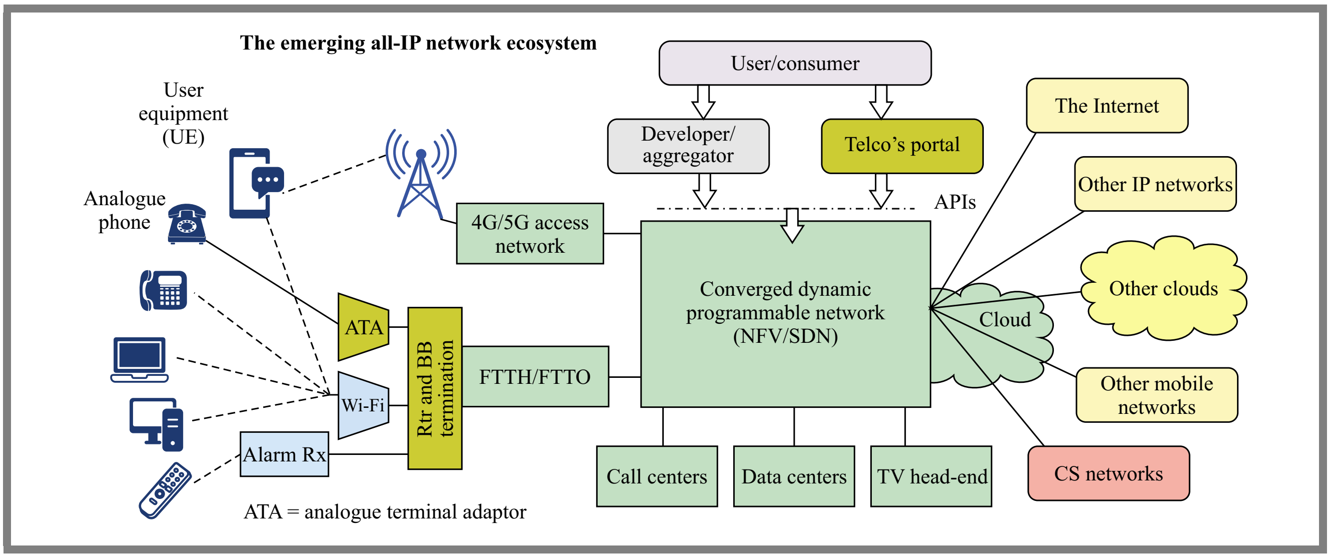

Fig. 5. The all-IP network ecosystem showing integrated fixed-mobile core with network API access.

Tab. 1. Summary of the progress towards PSTN closure in a range of countries.

Country	PSTN switch-off status	Notes
France	Target of 2030 for all operators in France	Closely following the copper network withdrawals
Germany	Substantially completed by 2019	Hampered by business customers not being ready
Italy	Gradual switch-off following fiber coverage towards 2030	
The Netherlands	Recently completed	
Norway	Completed by 2022	
Portugal	About 60% completed, linked to copper withdrawal program	
Spain	Telefonica substantially completed by 2024	
Sweden	PSTN switch off completed by 2010, now 90% of copper network closed	
UK	Both BT and VirginMediaO2 are aiming to substantially complete by 2027	Target of 2025 hampered by alarm systems and customer apparatus problems
Australia	Aims to be substantially closed by 2025, in line with move to National Broadband Network (NBN)	
Japan	Completed 2023	
New Zealand	Aiming for 2030	
Singapore	Completed in 2020	
USA	No national target date. Operators following their own plan, usually following fiber rollout	

velopers, once an application is initiated customers will, in a controlled way, have access to information about other customers location, ID verification, etc.). A wide range of feature and services will be covered by the suite of specified APIs.

Finally, the general direction of network development is towards a single IP core within a country to support both fixed and mobile access networks, with many of the control and transport functions being virtualized and transferred to the cloud, as illustrated in Fig. 5.

7. Author's Conclusions

The aim of this article is to pose some questions and potential concerns about the effect of closing the PSTN and transferring fixed-line telephony traffic to the emerging common IP core. I hope that these points will get taken into consideration in future cyber security work.

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