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A User's Perspective on Voice over WiFi Calling

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TEMS
WHITE PAPER

Orchestrating Network Performance

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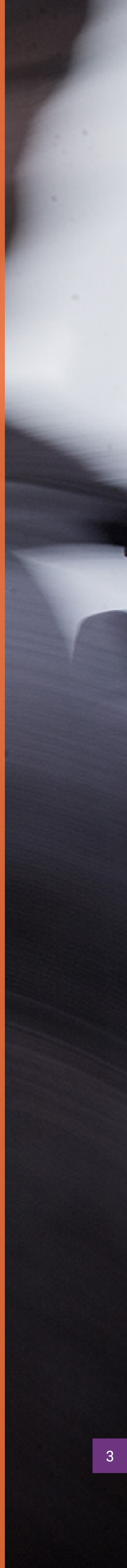
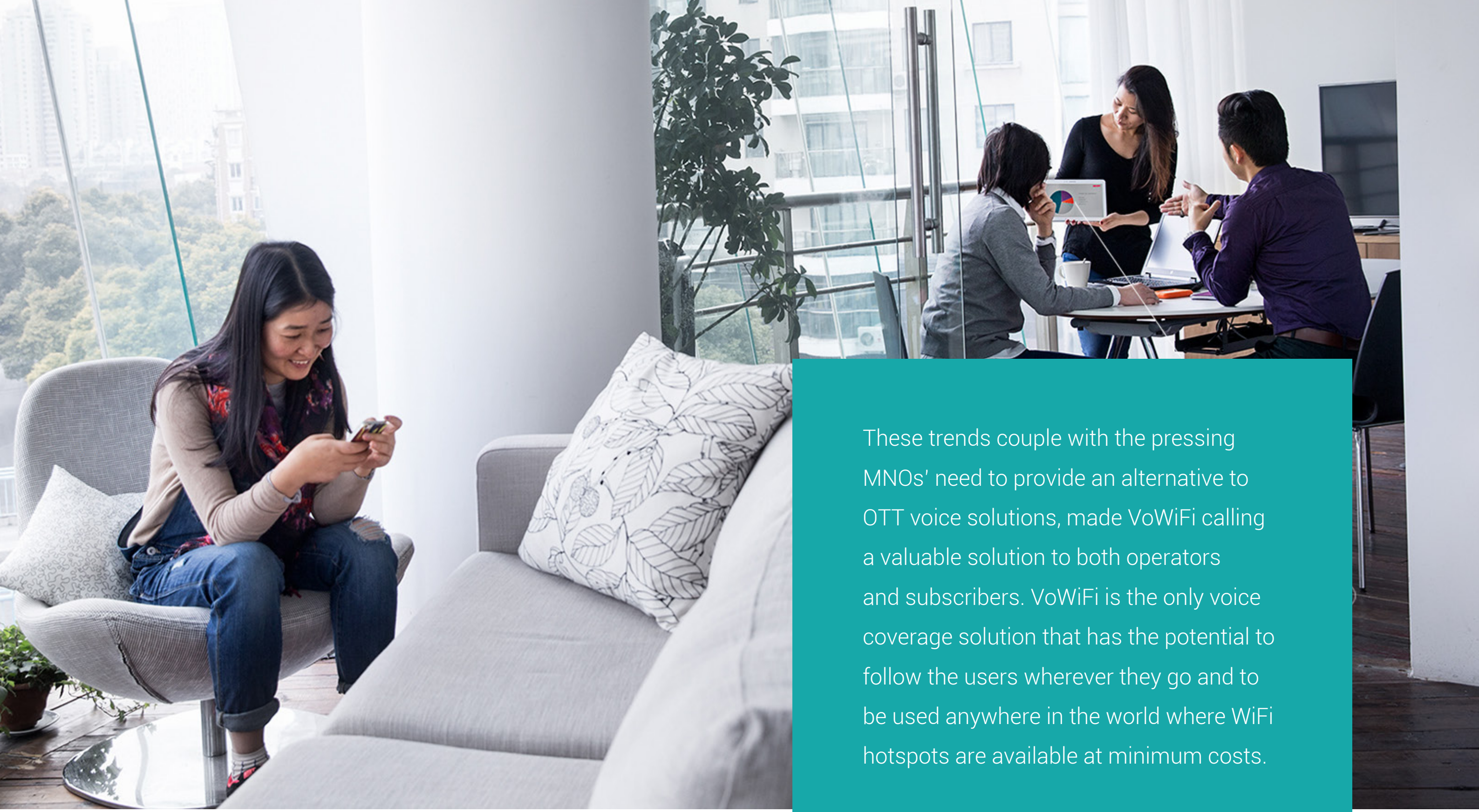




These trends couple with the pressing MNOs' need to provide an alternative to OTT voice solutions, made VoWiFi calling a valuable solution to both operators and subscribers. VoWiFi is the only voice coverage solution that has the potential to follow the users wherever they go and to be used anywhere in the world where WiFi hotspots are available at minimum costs.

1.0 Moving beyond traditional voice services

The impact of Voice over WiFi

Although still broadly available across the world, the traditional, well established, circuit switch (CS) mobile voice service with its well-known ability to provide subscribers high Quality of Experience (QoE) since the introduction of 2G services, is clearly fading. The evolution to 3.5G (HSPA+) already unleashed the technical means for Voice over Internet Protocol (VoIP) based solutions using mobility, such as the more or less free over-the-top (OTT) voice services like Skype and Viber. Lately, by the means of more widely spread and more mature LTE networks, VoIP solutions have become higher quality, and, more importantly, have allowed leading LTE carriers to deploy Voice over LTE (VoLTE) as the voice service solution with guaranteed QoE.

At the same time, mobile data WiFi offloading became one of the Mobile Network Operators' (MNOs) practices for coping with exploding data service demand. In addition, 2014 surveys [1] show the increasing behavioral users' trend to connect to WiFi whenever a hotspot is available.

With a high rates of home WiFi and smartphone ownership combined with as much as 11% poor mobile service coverage at home, it is understandable that 65% of smartphone users are automatically connecting to home WiFi. Similar trends are shown for various WiFi covered venues, such as hotels and airports.

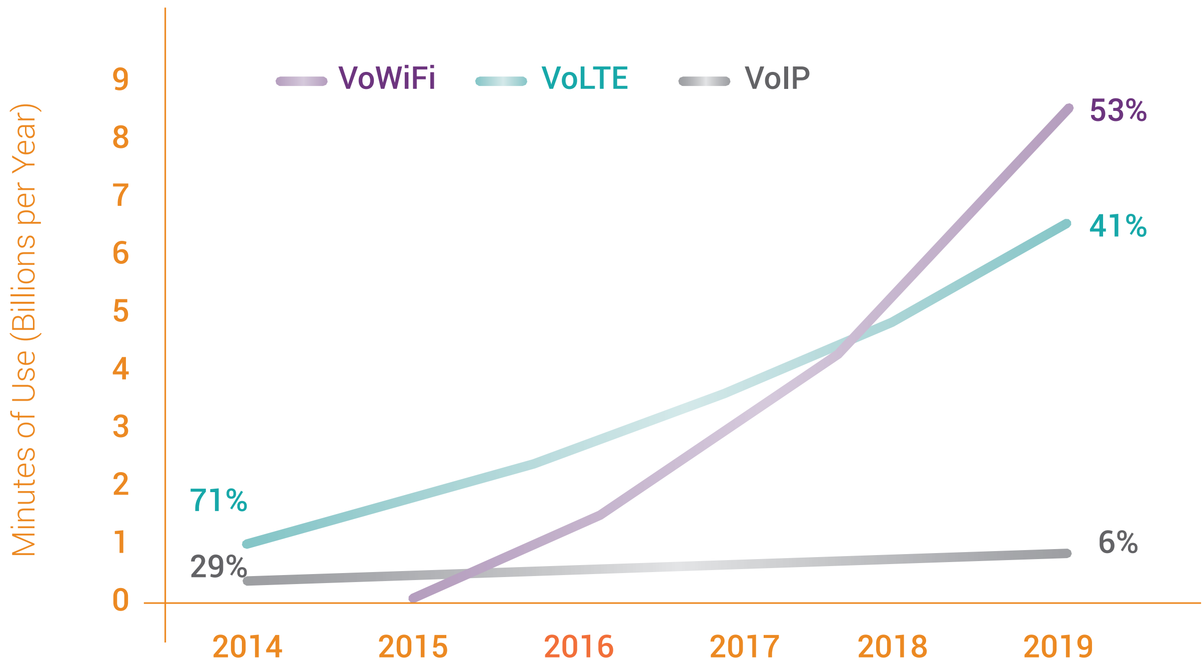
These trends couple with the pressing MNOs' need to provide an alternative to OTT voice solutions, made VoWiFi calling a valuable solution to both operators and subscribers. VoWiFi is the only voice coverage solution that has the potential to follow the users wherever they go and to be used anywhere in the world where WiFi hotspots are available at minimum costs. This is ensured by the defined 3GPP solution for seamless voice service when migrating between cellular and WiFi environments [2], [4]. Predictions show (*Figure 1*) that by 2019 the VoWiFi calling minutes will exceed VoLTE calling by 12% and regular VoIP calling by almost 50%. This is facilitated by the fast spread and increased number of smartphones which are required in order to provide VoWiFi service. According to Ericsson 38% of phones in use globally by the end of Q3/2014 were smartphones, and the GSMA predicts that the number will rise to about three quarters by 2020.

The push to improve voice coverage with its attendant reduction in subscriber churn can be accelerated using WiFi because of the fact that WiFi often offers the best quality radio frequency (RF) access in the home, in the office, or in many public venues (especially in tall buildings). Additionally, VoWiFi offers not only a seamless user experience for voice and messaging, but also easy-to-manage call billing enabled by IMS core network based on the (PCRF entity).

VoWiFi calling also offers operators an opportunity to combat OTT service providers. First, with WiFi coverage, the voice and messaging can be provided at lower costs, reducing in this way OTTs' price advantage. This is possible due to the fact that operators can rely on existing Wi-Fi networks instead of investing in new WiFi coverage footprint, and WiFi calling can share similar infrastructure with IMS-based VoLTE. Second, unlike OTT service providers, operators can offer a seamless call transfer support between WiFi and LTE (using VoLTE), and specific support in the device for migrating between the two networks. What's more, taking into account that the GSMA predicts that 2G and 3G deployments to be still ahead of 4G/LTE even as late as 2020, the 3GPP is currently working on defining the seamless VoWiFi handover to even 2G and 3G networks.

Therefore, a soon to be finalized 3GPP standardized VoWiFi calling protocol will provide the MNOs with the opportunity to decrease 2G/3G/4G radio network usage for voice and messaging, while subscribers will benefit from the lower cost for integrated VoWiFi use when roaming and traveling overseas. At the same time, VoWiFi can offer an alternative to mobile voice where either the mobile network either does not work at all, or is of poor quality.

However, the catch to this win-win scenario for both operators and subscribers, is that by implementing a Wi-Fi Calling solution operators have to give up some measure of control over QoS for voice, as the traffic will go over networks that they do not fully administer. However, through the ever-increasing capacity of Wi-Fi networks, with 801.11ac providing Gigabit speeds, and the improved capability to prioritize multimedia traffic, including voice traffic, QoS will not be too much of a major challenge in most cases. In addition, this is less of a problem for carrier WiFi scenarios, where the WiFi network becomes a "trusted" network inside the MNO mobile network.



Source: ACG, Cisco VNI Global Mobile Data Traffic Forecast, 2014-20

Figure 1: VoWiFi minutes of use exceed VoLTE by 2018
VoWiFi accounts for 53% of Mobile Ip voice by 2019

Today's market shows that operators do have different reasons why and when to introduce VoWiFi. Some VoWiFi front runners like T-Mobile in the U.S. and EE in the UK are offering the service as a business teaser to attract more subscribers, while others such as Sprint are offering it as an alternative solution during the transition to VoLTE. Regardless of these initial reasons, we think that ultimately all operators will offer VoWiFi calling service in addition to the voice services that they are already offering. Announcements underscoring this trend have recently come out from Verizon and AT&T in the US, Vodafone in the UK, and Rogers in Canada.

As we think about all the good things that can come from the implementation of VoWiFi, we must be cognizant that there is no such thing as a free lunch. All good things, all advances in technologies, come with their costs as well as their benefits. Therefore, in the following sections of the paper we will discuss the challenges that come with VoWiFi calling deployment, as well as how these can be identified and managed using the most appropriate testing tools. The main goal of VoWiFi calling is to offer users an increased and enhanced voice service experience and, taking this as foundational, the following discussion is customer experience centric.

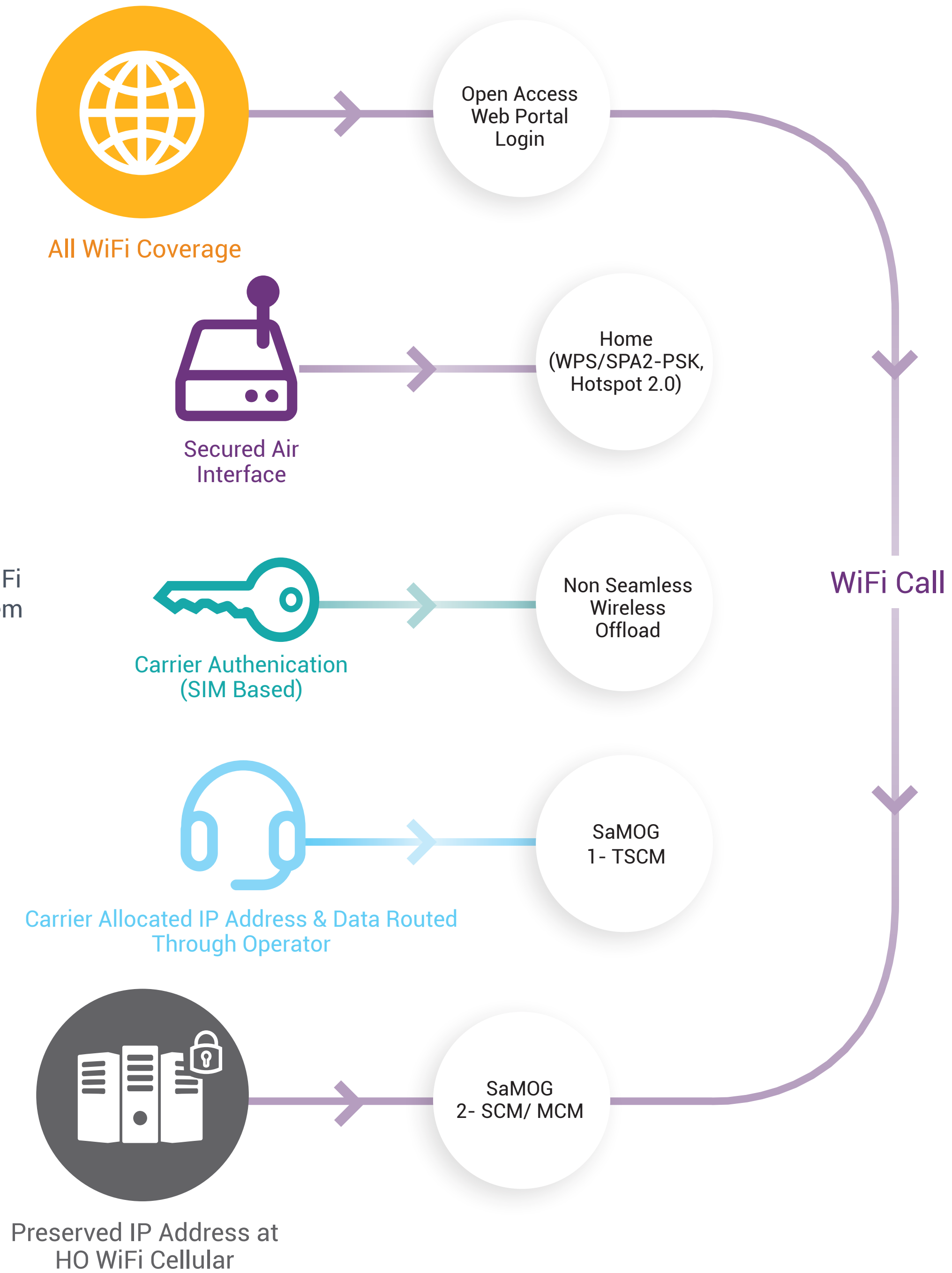


Figure 2: The WiFi calling ecosystem

2.0 A user's perspective on WiFi calling

Customer experience and WiFi calling

It shouldn't really come as a surprise that in order to first make it work, and then to maximize its benefits, a good understanding of VoWiFi service is required. Therefore, let's get into some details for understanding what is really meant by VoWiFi calling, which are the challenges raised by the service's deployment and more importantly, the implications on customer perceived experience.

2.1 An overview of the WiFi calling ecosystem

Actually, you might wonder why we are suddenly making so much noise around VoWiFi calling since this is not really new; it has been tried out already several years back by T-Mobile in the U.S and Rogers in Canada.

That solution called Unified Mobile Access (UMA) was based on the 3GPP defined Generic Access Network as part of the core. The solution requires significant assistance from the handset's cellular modem since the upper layers of the UMA stack, mobility management and Integrated Services for Digital Network (ISDN) call control, were not defined to be involved in the handovers between WiFi and 2G/3G, which were rather left to be handled by the intensive interaction between Radio Resources Control (RRC) layers within the two radio access technologies. Due to a fragile co-ordination at the RRC level, the implementation of these handovers from WiFi to the 2G/3G network proved unfeasible. Therefore, the UMA VoWiFi mostly faded out.

What makes VoWiFi calling a reality today is the possibility to seamlessly handover to cellular (to LTE/VoLTE initially and soon to come 2G/3G), as well as the fact that MNOs can make use of infrastructure already in place (e.g. IMS) with handset support, but without special stress on the handset's cellular modem. This is possible, due to the newly 3GPP defined [2]-[4] upper layers' features that allow mobility management and IMS (or ISDN in 2G/3G) call control to have visibility to the interaction going on at RRC levels and, therefore, ensuring that the handover decision is left to the intelligence of the device's dialer application layer. As of today, this is possible since the introduction of IOS8 on iPhone 6, 6+, 5C and 5S, as well as Android phones powered by Lollipop (5.0 and 5.1). Therefore, today's VoWiFi calling capabilities gravitate around the device, which becomes the centerpiece of the service's fulfillment, continuity and performance.

Now, being aware of the fact that there are various types of WiFi coverage, let's see which one can optimally support VoWiFi calling as defined by the latest 3GPP specifications. As seen in *Figure 2*, a VoWiFi call can only take place if 1) the WiFi access provides a secured air interface (possibly with different encryptions depending on the use case), and 2) the MNO performs the authentication as a non-seamless wireless offload (NSWO),and 3) allocates the IP address and ensures data routing through his network. The latter has been defined by 3GPP as the mobility feature of the GTP (GPRS Tunnel Protocol) at the S2a interface (*Figure 3*, WiFi access – mobile Core PGW interface), SaMOG – 1 (S2a Mobility Over GTP –Phase 1). However it is ensured, WiFi-to-cellular handover requires in addition the preservation of the IP address, which can be achieved using the enhanced SaMOG -2 (phase 2) protocol.

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2.2 Behind the scenes of a user's WiFi call

Now, that we know what today's VoWiFi calling requires, let's take a look to what actually happens behind the scenes when a user places a VoWiFi call, which he/she can do as of today if the operator supports the service and the used device is one of the above mentioned implementing a VoWiFi/IMS client.

Although fully transparent to the customer, when placing calls over WiFi the user's device can connect to the non-3GPP WiFi access network via "trusted" or "untrusted" solutions. The two solutions involve two different core network nodes along with two different interfaces S2a, respectively S2b (Figure 3). The nodes act as the gateway between the public internet and the rest of the operator's Enhanced Packet Core (EPC): a Trusted Wireless Access Gateway (TWAG) for "trusted" cases, and Evolved Packet Data Gateway (ePDG) for "untrusted" non-3GPP WiFi access cases. There are two main differences between these two solutions. The first one is the number of

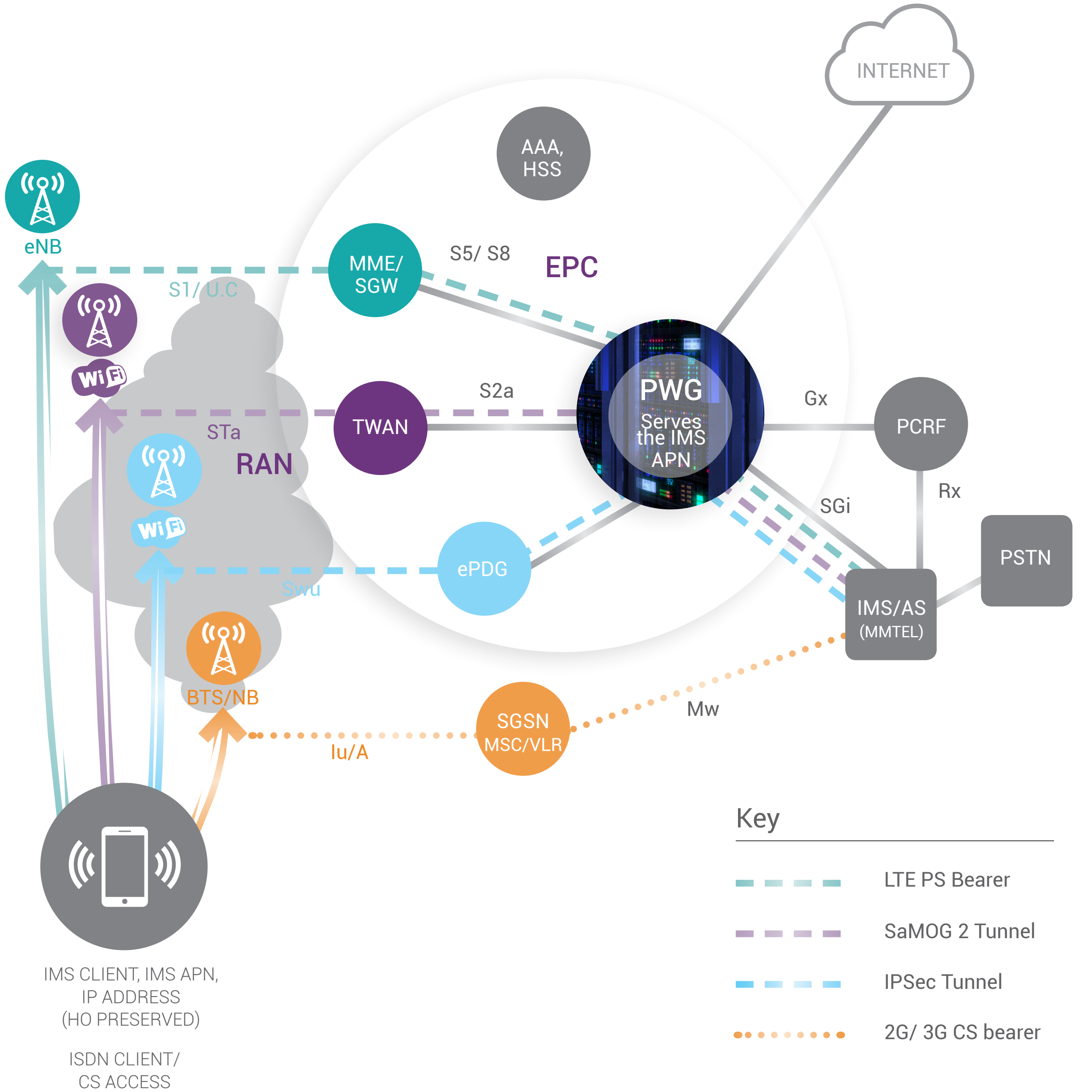

Figure 3: Behind the scenes of a WiFi call

levels of encryptions of the call path, with TWAN using only one level allowed by the introduction of HotSpot 2.0, and, therefore, ensuring significant battery life savings. The second one are the service's tunnels opened in each scenario. The optimal case is the one of trusted networks as described in Figure 2. However, secure WiFi calls with handover support can be fulfilled using WiFi untrusted access, as we'll further describe. Both solutions are carrier dependent.

Technical details about the two solutions' procedures and the required network nodes can be found in references [2]-[4]. For the purpose of this paper, let's see what happens behind the scenes when a customer places a VoWiFi call (Figure 3). As illustrated above in Figure 3, once the call is placed, a verified secure connection is established (on Sw interface) between the device and the ePDG for untrusted, or the TWAG (STa interface) for trusted non-3GPP access. The connection to ePDG is based on an Internet Protocol Security (IPSec) tunnel, while to the TWAG on SaMOG – 1/2 tunnel (*Figure 2*). Then, using the SIM credentials, the Internet Key Exchange version 2 (IKEv2) protocol allows ePDG (or TWAG) to fetch the security key and subscription information from the Home Subscriber Server (HSS) via an AAA node for authenticating the user's device to access the EPC and select an Access Point Node (APN) for the device. Once authenticated, the user's device can access the operator's Packet Gateway (PGW) which provides the IP address for his device to access this APN. The access to the EPC is based on the SaMOG 1/2 over S2a interface for trusted WiFi access or over S2b for untrusted WiFi access. At this moment of the call, session the request for bearer establishment is created and the VoWiFi call is forwarded between the Wi-Fi access network and the MNO's PGW. The device dedicated IP address is used by the VoWiFi (SIP) client as the contact information when registering to the operator's IMS network. To obtain static and dynamic policies, the PWG uses Diameter signaling over the Gx interface to the Policy and Charging Rules Function (PCRF) in the same way as it does for 3GPP access. Consequently, applications like IMS, enterprise VPN, and content delivery can set up dynamic policies (over the Rx interface) in the same way as is done for LTE access.

However, the best experience that customers get with VoWiFi calling compared to competing voice solutions (such as OTT service provider's voice), is the seamless transition to/from WiFi to cellular. Another great benefit is the real time service delivery which can be achieved based on the newly defined 3GPP protocols and procedure [4] for IP address preservation during a handover between 3GPP and non-3GPP network. Any policies assigned to the connection remain intact and, therefore, the choice of access technology used to carry the voice call is transparent to both the user and the IMS.

Figure 3 summarizes all these VoWiFi behind the scenes events within the context of the carrier provided mobile voice service ecosystem. Although not fully 3GPP defined yet, the handover to 2G/3G networks can be ensured by a circuit switch fall back (CSFB) type of solution benefiting from the Mw interface between the MSC and the IMS (already defined with CSFB), as well as making use of the handover decision role of the device within the VoWiFi calling context as explained above. The procedure is similar to SRVCC, but instead of having a single voice continuity, it uses dual voice continuity, in the sense that the device is configured with two numbers. One number is a Session Transfer Number (STN) (CS connection) and the second number is a Session Transfer Identifier (STI) (WiFi/IMS connection). The device "calls" one or the other of these two numbers during a call based on its decision for handover, which is determined by monitoring the RAN performance of 2G/3G and WiFi. All these processes are fully transparent to the user.

As can be seen, while fully seamless and transparent to the user, VoWiFi calling follows the same basic overall framework as VoLTE, except some modification in the IMS is required to handle the nature of WiFi compared to LTE and CS, as well as the use of the ePDG / TWAG nodes to access the EPC. In addition, unlike VoLTE, the device becomes the centerpiece of the VoWiFi platform, and it is the device that decides on handover events.

2.3 QoE centric challenges for customer satisfaction

Nothing comes for free, and that is very much the case with VoWiFi customer satisfaction for the MNOs. Having gotten used to mobile data offload to WiFi, MNOs might hope that adding voice to WiFi services or data offload would not be too terribly different. However, we reveal in this section that this potential initial hopefulness is not merited. Let's take a look at some of the most important challenges emerging from all the VoWiFi call events happening behind the scenes discussed above, and how MNOs can properly manage these.

2.3.1 Network selection

The challenges start with the cellular-to-WiFi integration, mainly the intelligent network selection performed by the Access Network Discovery and Selection Function (ANDSF) EPC entity that allows operators to seamlessly steer traffic in a manner that maximizes user experience. Improper network selection, such as doing so without comparative evaluation of the existing cellular network, or a strong WiFi network that is, however, rather heavily loaded, or to a network with lower backhaul capabilities can all result in the degradation of the user's perceived voice QoE. One of the most negative effects to voice quality from an improper network selection is expressed as frequent, variable and randomly distributed voice interruptions, the dreaded "ping-pong" effect between Wi-Fi and cellular access. This is a common characteristic of network selection taking place prematurely between networks with very similar signal strengths.

Passive and active monitoring of the interface between the two radio accesses allow the detection and troubleshooting of improper network selections as well as their overall impact of perceived QoE if voice quality (MOS like) evaluation is enabled. Dedicated drive and walk test solutions can be used to optimize ANDSF algorithms for network selection as well as to evaluate the device based ANDSF clients' performance within specific network conditions.

2.3.2 Voice continuity

As already mentioned, voice service continuity is ensured by using IP address preservation during handover between WiFi and cellular. However, not all the WiFi hotspots can support the 3GPP requirements and, therefore, MNOs need to be able to qualify WiFi hotspots for a full integration of WiFi-to-LTE/VoLTE handover initially, and later to 3G/CS. Monitoring solutions with MOS QoE enabled measuring capabilities help operators to qualify 3rd party WiFi hotspots, by verifying if these support voice cellular-to-WiFi handover mechanisms and what their users' perceived QoE is during these events. The latter can be also verified by using dedicated drive and walk test solutions.

Various implementations of IP address preservation involving different schemes can affect the duration of the handover to / from cellular-WiFi, and possibly cause voice interruptions longer than the perceived maximum acceptable values. Therefore, optimization towards low latency handovers is crucial in the VoWiFi service deployment. As a first step, using passive and active monitoring solutions can help MNOs deploy IMS components aligned with WiFi hotspots' location and traffic, ensuring therefore low latency even from the deployment phase. In addition, solutions running MOS like evaluations can also estimate the perceived impact of possible longer voice interruptions than acceptable limits possibly caused by signaling procedures affecting the duration of the handover to and from cellular-WiFi. Further on, dedicated drive tests can be used to evaluate latency's performance as well as fine tune it towards minimal values from real user perspective.

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2.3.3 VoWiFi QoS/QoE Requirements

Unlike mobile data offload or other real time services (even video streaming), voice service is the most sensitive to real time QoS/QoE continuity. Therefore, WiFi access QoS admission parameters need to be mapped to cellular parameters for voice dedicated traffic and default signaling bearers during the migration scenarios both to and from WiFi-cellular, or calls initiated on WiFi access. Depending on the implementation, this might involve additional signaling between TWAG and the device which can generate variable delays that are higher than the acceptable thresholds resulting in voice QoE degradations. In addition, poor implementation of the QoS mappings in TWAG or in the device can cause delay budgets and packet error loss higher than the maximum acceptable thresholds, and, therefore, cause degradation to the overall QoE voice service. Actually, all these threats to QoE are even more likely in the case of untrusted networks where the QoS levels are usually maintained at only best-effort levels. Therefore, in the scenarios in which untrusted WiFi access is used, operators need to have well-defined SLAs in place with WiFi provider partners to make sure that voice QoS/QoE levels are met while migrating between access networks. Because of this, MNOs need to be able to continuously evaluate and monitor WiFi partners' network performance. This performance monitoring can help MNOs to define different traffic models, codec bit rates, and usage profiles depending on such variables as the congestion levels of 3G, 4G, and WiFi hotspot, as well as on subscriber's segment and status.

QoS/QoE passive and active monitoring becomes crucial for the performance evaluation of roaming in IMS components for out-of-the-country scenarios. Such testing helps operators who are providing roaming by using WiFi, to deploy components out-of-the-country in order to improve users' experience.

2.3.4 Other VoWiFi Service Related Aspects

A complete customer experience comes with a fully integrated VoWiFi eco-system, adding on services such as SMS, voice mail and supplementary services such as caller ID, and call forwarding. Passive and active monitoring is required for detecting the requested service and where is the customer attached in real time in order to use the appropriate QoS admission for voice dedicated and default bearers.

2.3.5 Security

With the introduction of mobile data offloading to WiFi networks, cellular-to-WiFi security management became a hot topic. Now, with VoWiFi, MNOs need to make sure that security of the VoWiFi call is as secure as that provided for cellular-only voice service. In addition, operators need to provide a mechanism for governmental security agencies for call interception and subscriber location just like they have to do on their cellular-only network.

2.3.6 Devices' impact

The performance of the device's VoWiFi clients is key to VoWiFi service quality and highly device dependent due to a lack of VoWiFi client standardization. Poor performing error concealment algorithms implemented in a VoWiFi client can generate too frequent or too long periods of voice stretching or compression, and can result in degraded voice quality.

Additionally, the ANDSF in the device client uses the device's measurements of connectivity over WLAN (like channel quality, available bandwidth, latency, and internet connectivity) as well as cellular network conditions (like the downlink/uplink load). The performance of these algorithms using these measurements determines the quality of the decision making process of when to connect to the WiFi access network and, therefore, directly impact the voice service continuity while migrating to (or from) WiFi-cellular. Another factor impacting the handover-between-networks decision is the accuracy of the device based measurements, which can be affected by the device's battery level; depending on the device's performance, low battery level might affect its sensitivity and consequently its measurement accuracy. In particular, scenarios with connectivity to untrusted WiFi access, when two levels of encryption are used, are prone to poor measurement accuracy, and consequently lead to poor handover decisions. Monitoring and reporting information on the device's battery level should be used in troubleshooting handover behavior.

Considering all these aspects and especially considering the fact that the device becomes the center piece in VoWiFi calling, it becomes obvious that dedicated drive and walk testing that gathers device data and behavior plays a significant role in VoWiFi deployment and optimization.

3.0 From rollout to a new type of voice service

We have been discussing how VoWiFi service deployment still has important challenges lying ahead of it, and we explained in Section 2 how various testing solutions can help operators to cope with these very challenges.

Let's now take a look at how TEMS testing solutions, which address both passive and active network monitoring as well as drive and walk testing, can play an important role in VoWiFi service deployment and quality monitoring.

TEMS solutions can help operators manage all stages of early VoWiFi network testing, from the new service's roll-out in deciding on WiFi hotspots' qualification, to the optimal distance between the hotspot and the IMS network for ensured low latency handover, all the way to complex roaming outside-the-country scenarios and the required IMS components for high quality customer experience.

Once the VoWiFi service is deployed and stable, MNOs can proactively optimize the cellular – WiFi integration as well troubleshoot VoWiFi service problems towards higher voice service QoE targets for accessibility, continuity, retainability as well as voice quality (MOS). With TEMS passive and active monitoring, operators can decide on the best traffic bearers' QoS profiles, as well as evaluate the performance of supplementary add-on services. Our monitoring solutions also help evaluate and manage SLAs with WiFi partners.

As we already discussed, the device is the center piece of the VoWiFi service. Therefore, understanding the device's behavior, feedback and reaction to various network conditions in addition to the real end user QoE evaluation, makes drive and walk test data especially valuable for VoWiFI service's performance evaluation. TEMS drive and walk testing solutions complete the end-to-end VoWiFi QoE evaluation by analyzing problems related either to the device itself or to cellular or WiFi access, but more importantly can play a significant role in optimizing the call continuity during the handover between the two radio accesses. In addition, dedicated drive and walk testing can be used to troubleshoot and analyze problems first identified by TEMS active and passive monitoring test platforms.

Drive Test

Even though VoWiFi calling is in an early phase with only a small selection of available commercial devices supporting call continuity across the two radio accesses, we have already prototyped drive test centric use cases for VoWiFi with continuity to LTE. Along these lines, we are tailoring the already well established TEMS VoLTE analysis solutions to VoWiFi calling, such as call control performance and root cause analysis from the RAN to the IMS (e.g. IMS registration statistics, delay), RTP/IP troubleshooting (e.g. packet loss, jitter), as well as device centric analysis (e.g. VoWiFi client performance, battery life). You will recall that the latter plays a significant role in the call continuity across the two RANs. For example, the battery life of the device can possibly explain why the device made poor RF measurements that can results in wrong decision making when selecting the network, or in a ping-pong effect. In our developments we accord special attention to call continuity since it is crucial for the launch of VoWiFi, and it is similar to the SRVCC scenario for VoLTE. Therefore, we monitor the EPC allocation as well as the QoS negotiation taking place during handover.

The end to end performance evaluation is ensured by QoE measurements using our unique on device POLQA solution, which ensures that engineers and technicians are testing like a real user. Along with POLQA measurements we also perform mouth-to-ear delay measurements which are very important in accurately characterizing the perceived latency during handover. In addition, our correlations of the speech interruptions during handovers can help to optimize the handover process and to also easily rule out handover problems as root cause in certain cases of voice degradations caused by significant interruptions.

Active and Passive Monitoring

TEMS VoWiFi monitoring test suite is currently focused on initial deployments, which require both VoWiFi as well as femto cell scenarios, since specific routes are added and need to be tested in the IMS femto cell infrastructure for the VoWiFi service. If the routing does not work properly, then the VoWiFi service is fully affected even from the beginning of the call. The routing testing results are needed in order to be able to correlate the functionality and interoperability of the two scenarios, as well as to detect the root cause of the possible malfunction and whether the femto cell or VoWiFi access point is the source.

As it can be seen in Figure 4, our solution currently aims untrusted WiFi using ePGW and taps in the 3G/4G and WiFi interface as well as IPsec tunneling at the ePGW/PGW and at various IMS interfaces generating a measurement database for each tested use case. The TEMS Monitor Master probe performs test cases in order to measure service availability and quality of service as well as to identify problems that diminish these, and what the root causes of these problems are.

The femto cell scenario's use cases are designed to verify the parity of the macro and femto network for VoWiFi service, while the VoWiFi scenario's use cases aim to detect if the features of the VoWiFi service relying on this parity is working correctly. The test use cases for each scenario are listed in the Table 1. Before starting the voice calls, the VoWiFi clients used for testing need to "rove-in" and the procedure covers steps such as IPSec Setup, IMS APN and registration, and SBC Discovery.

TEMS currently also develops a cloud automated test generation platform to support new VoWiFi deployments with the above type of test scenarios.

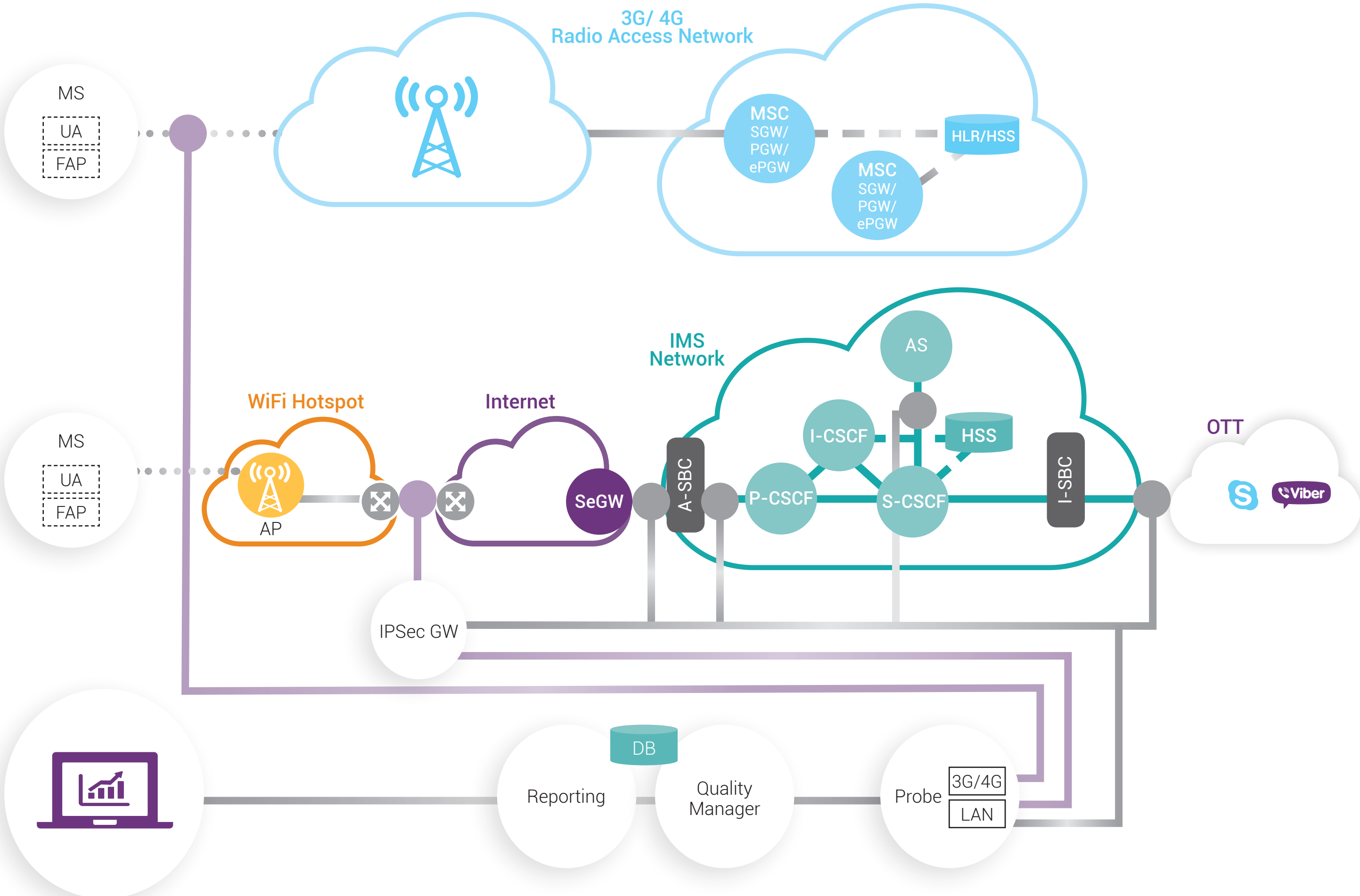

Figure 4: VoWiFi monitoring

Femtocell test use case Scenarios	VoWiFi test use case Scenarios
1. 3G/ 4G Attach - Detach + Rove-in + Incoming call (from a mobile and/ or PSTN) + Incoming SMS	1. Voice call VoWiFi to VoWiFi/ OTT/ Mobile/ PSTN
2. Rove-in + Rove-Out + 3G/ 4G Attach + Incoming call (from a mobile and/ or PSTN) + Incoming SMS	2. Voice call OTT / Mobile / PSTN to VoWiFi
	3. SMS VoWiFi to Mobile
	4. SMS Mobile to VoWiFi
	5. Various voice supplementary services

Table 1: Test use cases

4.0 Conclusions

US Mobile Consumer predicted that by 2019 the VoWiFi calling minutes will exceed VoLTE calling minutes by 12% and regular VoIP calling by almost 50%. This is anticipated due to the fact that VoWiFi is the only voice coverage solution that follows the users wherever they go, and can be used anywhere in the world where WiFi hotspots are available at minimum cost, for subscribers and operators alike. VoWiFi with ensured mobility across the two radio accesses, 3GPP and non-3GPP/Wi-Fi, can become a strong competitor of OTT solutions.

VoWiFi support provided by the 3GPP Release 12 mobility features and HotSpot 2.0, iPhone 6, 6+, 5C and 5S (IOS 8) and Android Lollipop (5.0 and 5.1), allowed operators like T-Mobile and EE to already launch VoWiFi. Many other operators have recently made announcements about their plans to launch VoWiFi services such as Sprint, Verizon, AT&T, Rogers, and Vodafone UK.

Although a win-win game for both for users and operators, VoWiFi service deployment still faces significant challenges that emerge from the voice service's native requirements of real-time, high and consistent QoS/QoE delivery, as well as from new communication protocols and network entities that need to be introduced. Challenges starting with the optimization of the WiFi selection and integrations, cover issues related to network aspects such as interoperability, continuity across radio accesses, QoS/QoE requirements and roaming. In addition, security and supplementary add-on service, especially in WiFi-to-cellular migration, as well as international roaming scenarios are of significant concern for MNOs aiming to provide high levels of quality of service.

With deep thought leadership, TEMS develops VoWiFi solutions to help operators from the early VoWiFi service's roll- out through its optimization and towards a stable service state. TEMS solutions address passive and active monitoring and drive and walk testing. Using our end-to-end solutions focused always on end user QoE, MNOs can proactively optimize the cellular – WiFi integration, interoperability, continuity and roaming aspects of the service. When testing these VoWiFi service aspects, it is important to be able to troubleshoot VoWiFi service problems while targeting high voice QoE for accessibility, continuity, retainability and voice quality (MOS). Drive and walk testing solutions complete the end-to-end VoWiFi QoE evaluation by analyzing problems related either to the device itself or to cellular or WiFi access. More importantly, based on the device's VoWiFi role as center piece of the service's fulfillment, device measurements and reports collected in dedicated drive and walk tests are crucial for the optimization of various VoWiFi scenarios.

5.0 References

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