Remote assistance provides an opportunity to offer better and tailored maintenance to the customer, making the service also faster and cheaper

ABSTRACT

This paper reviews currently available hardware and software for remote assistance during transformer maintenance and provides a newly created business model. Recently, a large number of wearables has entered the market, which could help support technicians in their maintenance work. This paper will focus on three of these wearables. Additionally, some software packages that are available offer a possibility to see what the technicians are doing at a certain point in time. It has been established that in order to provide a tailored remote assistance to customers, the remote assistance paradigm must include five key components, and they are: expertise, infrastructure, application and platforms, security and privacy, and a business process and business model. The resulting paradigm and the overlaying

Assistance as a Service

Remote assistance during transformer maintenance

1. Introduction

Over the last decades, many processes and workflows have changed significantly, especially in production environments, with some processes becoming more and more complex and sophisticated as a result. In order to meet these challenges, there are new information systems that we can resort to. However, although more and more activities are done automatically, there are still some service operations, especially on units such as power transformers, that have to be done manually [1]. In production environments, some of the tasks are recurring operations, which are controllable and clearly defined as a process [2]. In contrast, service and maintenance tasks are mostly uncontrollable, undefined and unstandardized, which is why these activities often require help from experts. The aim of this paper is to provide a stack of key components in order to offer remote assistance to engineers on site.

With remote assistance energy plants can achieve higher availability, while the failure rate and the amount of incorrect assemblies during maintenance can be decreased

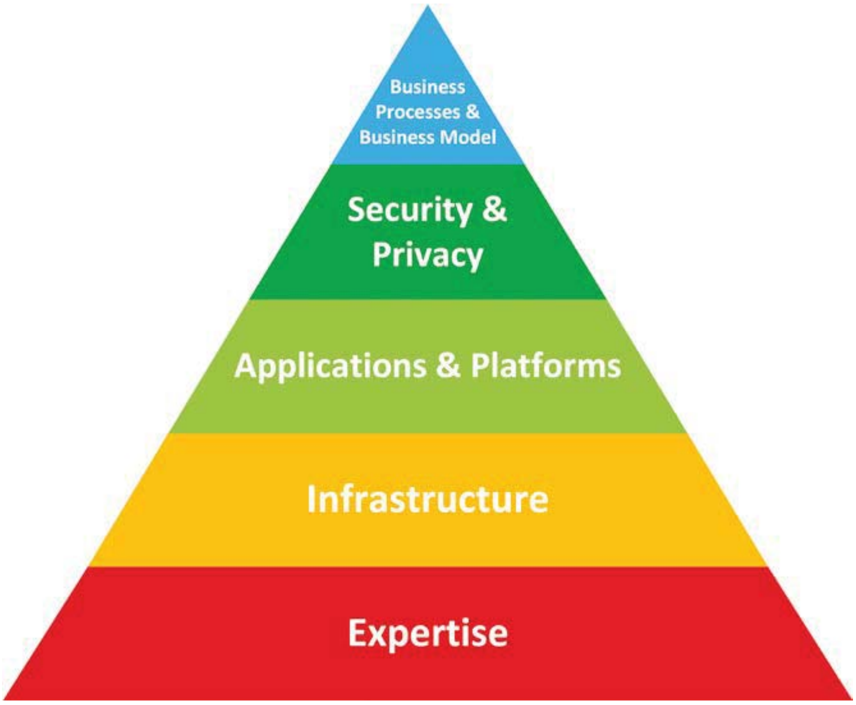

Figure 1. *Assistance as a Service* stack

business model is called "assistance as a service".

KEYWORDS

assistance, Assistance as a Service, maintenance, remote help

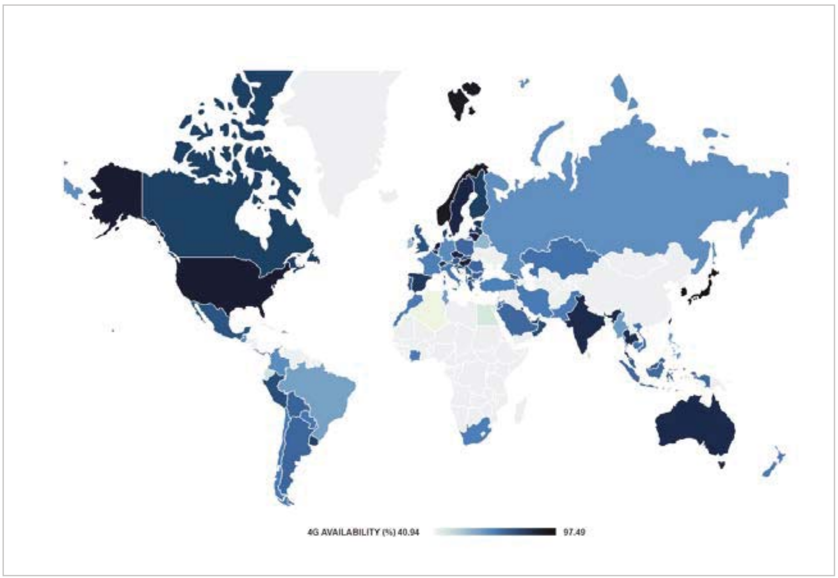

Figure 2. 4G coverage across the world [8]

2. Challenges in power transformer maintenance

Power transformers are complex systems and key components of every electrical network. Each fault in any one of these units may cause blackouts over a long period of time, large profit setbacks for companies and a significant loss of reputation. Furthermore, a large number of manufacturing companies need power transformers to power their machines. The availability of both power plants and industrial plants is also regarded as a key factor in the industry [3]. Therefore, appropriate inspection and maintenance of transformers is necessary. However, it is not always possible to send specialists to a substation due to travel restrictions. Bigger substations, such as power plants, are often located far away from cities, which makes the travel expensive and complicated.

In case of minor maintenance activities, travel costs are too high in relation to the efforts required on site. Also, in case of unplanned maintenance experts may not be immediately available, so engineers with less experience might have to perform the maintenance activities. Although service is a matter of trust, an implicit knowledge is necessary for most of these activities.

3. Remote assistance

According to Güntner et al. [4], almost 60 % of companies will want to use mobile devices during service and maintenance activities within the next five years [4]. An internal innovation project called *Smart Service* was run by a large transformer manufacturer in Europe with an aim to support transformer maintenance engineers during their complex activities. Unlike the assistance performed via outdated telephones, the remote assistance offered a possibility to collaborate over a digital network [5]. Even if the expert and the engineer are located in different time zones, it is possible to offer assistance with works that might not have been possible by a person before.

A vast advantage of remote assistance is that customers can decide on their own how much of assistance they need. Customers are only paying for the resources and work that they really need. Furthermore, with this service it is more likely that the desired expert will be available during the maintenance activities. In case of remote assistance, service technicians do not need to have face-to-face contact with customers [6]. However, the expert needs a certain degree of situation awareness, which means that engineers will use only as much assistance as they really need.

The key components of successful remote assistance are expertise, infrastructure, applications and platforms, security and privacy, and business processes and business models

Figure 3. (a) binocular and non see-through wearable, Samsung Gear VR [10]; (b) binocular and see-through wearable, Epson Moverio [11]; (c) monocular and non see-through wearable, Tac-Eye 2.0 [12]; (d) monocular and see through wearable, Google Glass [13]

4. Assistance as a service

> **With a comprehensive availability of the 4G network around the world, the key requirement of the infrastructure can be fulfilled in almost every part of the world**

There are a number of examples, both inside and outside IT, where the annex *as a Service* is used. As an example, JaaS – *Justice as a Service* – is used when attorneys help customers in their fight for justice or compensation [7]. This paradigm is called *Everything as a Service* (EaaS) and will also lead into a paradigm change in maintenance and service business.

During the *Smart Service* project, some remote assistance scenarios were tested, showing there is a potential market here. Therefore, a new business model was created and named AaaS – *Assistance as a Service*. While testing the approach, it was established that this paradigm must include five key components which have to be fulfilled in order to provide successful remote assistance to customers. These are:

- Expertise
- Infrastructure
- Applications and platforms
- Security and privacy
- Business processes and business models

4.1 Expertise

Expertise forms the basis of the stack, as seen in Figure 1. Without the domain knowledge, assistance is meaningless and not applicable. With remote assistance, it is more likely that the desired expert will be available immediately. For example, in some cases field engineers have to wait more than one week to get working permissions. As daily fees for field engineers are expensive, this means that customers have to pay thousands of euros for unproductive dwell times. In this case. it would probably be cheaper to send the customer's engineers to the site and help them via remote assistance. Furthermore, a single expert can work on more than one site in parallel, even if these sites are located in different places. Another benefit is that there is a possibility for a conference call if more than one expert is needed.

4.2 Infrastructure

A comprehensive availability of broadband networks is necessary for both parties. This is important both for video and audio conferring, as well as for sending data over the network. According to recent studies, in more than 80 countries over half of the area is covered by 4G [8]. In the U.S. for example the coverage is more than 90 %. Poor network quality and low bandwidth will lead to dissatisfaction with remote assistance.

In addition to fast internet, it is important to select an adequate device for communication. In case of transformer maintenance, service technicians often need both their hands free and they have to remain mobile, so a wearable device would be appropriate. There are basically four types of wearables available [9], as illustrated in Figure 3:

- binocular and non see-through
- binocular and see-through
- monocular and non see-through
- monocular and see-though

A literature review has shown that some key criteria have to be met in order to select an adequate wearable for the maintenance context [9], [14], [15], [16], [17], [18], and these include:

- Wearing comfort
- Battery lifetime
- Field of view
- Navigation
- Wearing comfort

In case of service activities, the device might have to be worn over a longer period of time. This makes the musculature in the neck area stressed, even if the wearable itself is not heavy. Some devices use nose bridges, brackets for ears or some sort of a neck holder. The device should not be too heavy, but it should be rugged in case it falls to the ground. The device should also accommodate individual wearing settings. It has to sit well because the wearing feeling is mostly influenced by the mounting method. Users have to trust that device is sitting well and won't come off suddenly.

Figure 4. (a) Microsoft Hololens, binocular and see-through [19]; (b) Daqri Smart Glass, binocular and see-through [20]; (c) Realwear HMT-1, monocular and non see-through [21]

4.2.1 Battery lifetime

The duration of the assistance needed during transformer maintenance may be between several minutes to hours. Even if the device is not needed during the entire working process, the battery should be durable and have a battery lifetime of approximately one working day. There is nothing worse than the device battery running empty when the assistance is really needed. The battery of the device should be fast loading or replaceable.

4.2.2 Field of view

The normal field of view (FOV) for humans is 200° horizontally and 135° vertically [18]. The user's sight should not be limited significantly and the user should at no point lose the situational perception. With a limited field of view, the eyes are stressed, which leads to eyestrain and dry eyes [9]. A wide field of view is desirable and also linked to improved user acceptance.

It should also be possible to wear eyeglasses underneath the wearable.

4.2.3 Navigation

The operating system inside the wearable must be easy to navigate, and there are three input methods that should available:

- Buttons directly at the device
- Speech
- Gestures

None of these three types are useful during maintenance operations, so a companion application should be available. These applications make it possible to interact with the device, offering for example a keyboard which makes entering the text easier.

During the *Smart Service* project, tests were conducted with two pairs of binocular and see-through wearables: the Microsoft Hololens, Fig. 4a, and the Daqri Smart Glass, Fig. 4b, and with a monocular and non see-through wearable the Realwear HMT-1, Fig. 4c. Binoculars which are non see-through are not suitable for maintenance activities. Also, augmented reality is not necessarily needed. Additionally, it has to be clarified if a full-face display is needed. If not, a wearable with a micro display or a tablet may also fulfil the needs during remote assistance.

What was also concluded is that the situational perception suffers when full face displays are used. For example, the persons doing the tests were not able to see harmful items even though they occurred in their normal field of view. With the Realwear HMT-1, having a micro display mounted on a small arm, it is possible to move the display out of the field of view whenever it is not needed.

Furthermore, it was established that the Hololens and the Smart Glass are becoming heavy when worn although their weight is only around 370 g. Wearing the Hololens or the Daqri Smart Glass underneath a helmet is physically exhausting over a longer period of time. Therefore, a device used needs to be comfortable to wear for the user.

In the production environment, it is often necessary to wear personal safety equipment such as safety glasses or safety helmets. If engineers wear the Hololens, it is necessary to wear safety glasses underneath. Daqri Smart Glass, however, would count as personal safety equip-

With satellite internet, even the substations located far away from bigger cities, such as offshore wind farms, can be visited virtually

Table 1. A comparison of Microsoft Hololens, Daqri Smart Glass and Realwear HMT-1 wearables (see [20], [22], [21])

	Microsoft Hololens	Daqri Smart Glass	Realwear HMT-1
Type	Binocular see-through	Binocular see-through	Monocular non see-through
Weight	579 g	312 g + 425 g	370 g
Processor	1 GHz	3.1 GHz	2.0 GHz 8-Core
RAM	2 GB RAM	not specified	2 GB RAM
Internal Storage	64 GB	64 GB	16 GB
Operating System	Windows 10	VOS (Visual Operating System)	Android 6.0.1
Battery Life	4-6 hrs available, 16500 mWh	8-10 hrs usable, 5800 mAh	8-10 hrs usable, Battery Replaceable
Camera	15° Diagonal HD video camera	166° Diagonal HD Fish-eye Lens	20° Diagonal 16 MP
Video	not specified	1080p at 30fps	1080p at 30fps
Field of view (FOV) diagonal	70 degrees	44 degrees	almost unlimited
Price per unit	€4,574	€4,380	€1,620

Table 2. Results of the hardware evaluation

	Microsoft Hololens	Daqri Smart Glass	Realwear HMT-1
Wearing comfort	2	1	3
Battery lifetime	1	2	3
Field of view	2	1	3
Navigation	2	1	3
Storage	3	3	1
Processor & RAM	1	3	2
Camera	3	1	2
Price	1	2	3
Result	**1.875**	**1.75**	**2.5**

ment (PSE). Additionally, the Hololens is heating up at the processing unit, which is located right above the ear. The computing unit of the Daqri Smart Glass is an external device, which can be mounted on a belt.

With regard to menu navigation during usage, both Hololens and Daqri Smart Glass use gestures. It took some time for the users to learn the gestures, but after a short time, they got more and more accustomed to them. In comparison, the Realwear HMT-1 uses speech recognition for navigation. This is not very suitable in production environments with high sound intensity [20], [22], [21].

A comparison of the three devices is presented in Table 1.

Table 2 presents the results of the research and field tests on these wearables, based on the surveys and interviews conducted after the field tests. The devices were ranked from one to three on a number of criteria, where three was the maximum value.

Based on these results, it was decided to proceed with Realware HMT-1 and take further tests. Despite of having the smallest display, this device ranked highest for wearing comfort. Furthermore, it offers a possibility to replace the battery if needed, and uses an android operating system which is common in many devices.

4.3 Applications and platforms

It is necessary to have a supporting application or platform to share knowledge during maintenance activities. So, proceeding with Realwear HMT-1, the following communication applications were evaluated: Skype for Business, Evocall and Essert Augmented Portal, as presented in Table 3.

Table 3. A comparison of Skype for Business, Evocall and Essert Augmented Portal applications

	Skype for Business (Office 365 Enterprise E5)	Evocall	Essert Augmented Portal
Connection type	Routed over Skype Server	Point to Point (WebRTC)	Point to Point (WebRTC)
Web app available	Plugin necessary	Yes	Yes
App available	Yes, but not for HMT-1	Yes	Yes
Multi-conferencing	Yes	No	No
Annotations	No	Yes, static images	Yes
Pointer functionality	No	No	Yes
Shared screen	Yes	No	No
Chat function	Yes	No	Yes
Reporting	No	Yes	Yes
Price per year / per license	**~ €370**	**€5,280**	**€896**

Figure 5. Annotation with Essert Augmented Portal seen through Realwear HMT-1

After discussions and interviews with the target group, the following criteria were established as important for a software platform to be usable during maintenance activities:

- Usability and user acceptance
- Annotations or pointer functionality
- Multi-conferencing
- Chat function
- Reporting
- Price

A single expert can provide remote assistance to more than one site in parallel, even if these sites are located in different places

4.3.1 Usability and user acceptance

The key factor for the software is that it has to be accepted by the users. The user interface has to provide most important functionalities at a glance, so that service technicians can navigate it quickly. For example, it should be easy to select the desired expert. The three compared systems all have a user-friendly web interface. Although Essert offers many possibilities and features, the user interface appears to be tidy and well-structured. Depending on the bandwidth and the selected device, all three systems have equal video and audio quality.

4.3.2 Annotation or pointing functionality

The expert should have the possibility to point to or annotate certain things in the video, as shown in Figure 5. In the field tests, it was discovered that some field engineers, if they are non-native speakers of the language spoken by the expert, have problems understanding the expert. The pointing functionality helps field engineers to identify objects and makes it easier to understand what the expert is talking about. According to M. Rice et. al. [23], visual annotations are a key factor for successful remote assistance. But the usage of annotations on static images is dangerous, especially when using head-mounted devices. They may cause a loss of orientation for a short period of time, which may become dangerous in industrial environments. Annotations in a live video stream may limit one's sight. This means that annotations are helpful, but they must be used carefully. Additionally, it should be possible to send documents or drawings, which might also be annotated.

4.3.3 Multi-conferencing

In some cases, one expert alone is not capable of resolving the issues on site, so it is important to have the possibility to make conference calls. With this feature, a group of people can help one or more engineers on site.

4.3.4 Chat function

In some cases, especially in noisy environments, some of the commands to the field engineers are not understandable. In this case a chat function, where expert can write down requests, is necessary. Furthermore, it is also possible that engineers on site have to change some parameters of a software. Therefore, it is easier to send text messages with the desired parameter than describing the values.

4.3.5 Reporting

After finalizing a remote assistance session, it should be easily possible to create a report. For example, it should be possible to create a PDF document with all participants written down, the time span of the conference call or the text messages sent. This report can be used for internal documentation or as a proof for customers.

4.3.6 Pricing

Finally, the price of the system is also important. All three software packages use yearly subscriptions which are based on the amount of users using the system.

Table 4 shows the results of the research and field tests of the three platforms. The results are based on the interviews, detailed (usability) tests and surveys conducted after the field tests. Those items which are easily measurable (like pricing) where accounted accordingly. The platforms were ranked from one to three for each criterion, with three being the maximum value.

4.4 Security and privacy

The traffic between the expert and the field service engineer must be secured and encrypted because sensitive data may be transmitted. These transmissions may contain operational data or, in some cases, confidential structures or designs. The evaluated platforms use encrypted peer-to-peer connection between the expert and the field engineer. Skype, for example, does not establish peer-to-peer connections – the traffic is always routed over an external server.

A peer-to-peer connection can be established with the usage of Web Real Time Communication (WebRTC) [24]. Several methods of securing the connection can be considered, for example DTLS (Datagram Transport Layer Security) or SRTP (Secure Real Time Protocol). For even more secure communication, identity providers such as OAuth or BrowserID can be used. [25] Nevertheless, the connection from the service technicians to the experts must be established quickly. If the waiting period lasts too long, the platform will not be accepted by the user.

In the scenario illustrated in Figure 6, Alice and Bob are proving their identity through several identity providers. The connection to the signalling server, which notifies the corresponding party that there is a request, is secured by https. The media transmission (video and audio stream) is direct between the two browsers and secured by DTLS and SRTP.

4.5 Business processes and business model

Although this type of assistance is faster and cheaper than sending people directly to site, a business model for revenue strategy needs to be implemented. So, it might be possible to offer free remote assistance over a defined period of time. If more time is needed, the billing may be introduced at cost, which might be cheaper than covering the cost of the flight, daily allowance and other fees.

The time of assistance can be recorded and accounted by minute. With the use of video recording, it is easy to document the work done and these videos may then be used during training. Another advantage is that customer satisfaction may increase due to the quickness of the service. This may also lead to a long-term partnership between the vendor and the customer.

With the Internet of Things approach, it is possible to collect transformer data at a single point [26]. Central knowledge modules can be implemented which create correlations among identically constructed transformers even though they might be located in different substations. With this approach it is possible to change the maintenance strategies from "push" to "pull", which means that vendors may recommend maintenance actions to customers. The maintenance operations may be conducted by personnel of the customer or third-party companies with remote assistance. The transformer may therefore be operated by the manufacturer with all responsibilities regarding reliability, availability, maintainability and safety (RAMS). These strategies may lead to management of a complete transformer life cycle and long-term contracts.

If it is not possible to solve a problem with remote assistance, further help

Table 4. Results of the software evaluation

	Skype for Business	Evocall	Essert Augmented Portal
Usability	2	3	3
Annotations	0	2	3
Chat function	2	1	3
Multi-conferencing	3	0	0
Reporting	0	2	3
Price	3	1	2
Results	1.66	1.5	2.33

The traffic between the expert and the field service engineer must be secured and encrypted because sensitive data may be transmitted

must be available immediately. Additionally, a remote assistance system can be used to get a rough overview of the help which is needed on site. In addition to the operational data, with this overview it might be easier to send the correct engineer to site or create tailored offers to the customer.

Conclusion

The stack presented in Figure 1 helps to ensure a better process during remote assistance in combination with smart devices. This provides an opportunity to offer better and tailored maintenance to the customer and makes the service faster and cheaper. Consequently, energy plants can reach higher availability, and the failure rate and the amount of incorrect assemblies during maintenance can be decreased. In addition, both parties may save a significant amount of money. With a comprehensive availability of the 4G network around the world, the key requirement of the infrastructure can be fulfilled in almost every part of the world. In the future, the fifth generation of mobile networks (5G) will be available, in some parts of the world as soon as by the end of 2018 [27]. If no 4G or 5G is available, then satellite internet may be used, but this hardware is expensive. With satellite internet however, even the substations located far away from bigger cities, such as offshore wind farms, can be visited virtually.

While we have seen that the wearables are useful, they have to be used depending on the needs of the engineer on site. If no augmented reality support is needed, a wearable with a micro display will also be suitable. Whenever it is not necessary that both hands are free, and only a brief help is required, a tablet or smartphone will do. Thus, it is not necessarily required to have or bring expensive hardware on site, which minimizes possible risks or issues with customs clearance.

However, in some cases it may be prohibited to use devices with cameras on site, such as in nuclear power plants or military zones, which makes remote assistance impossible. Due to that fact, the "traditional" service will also remain a key factor in the future.

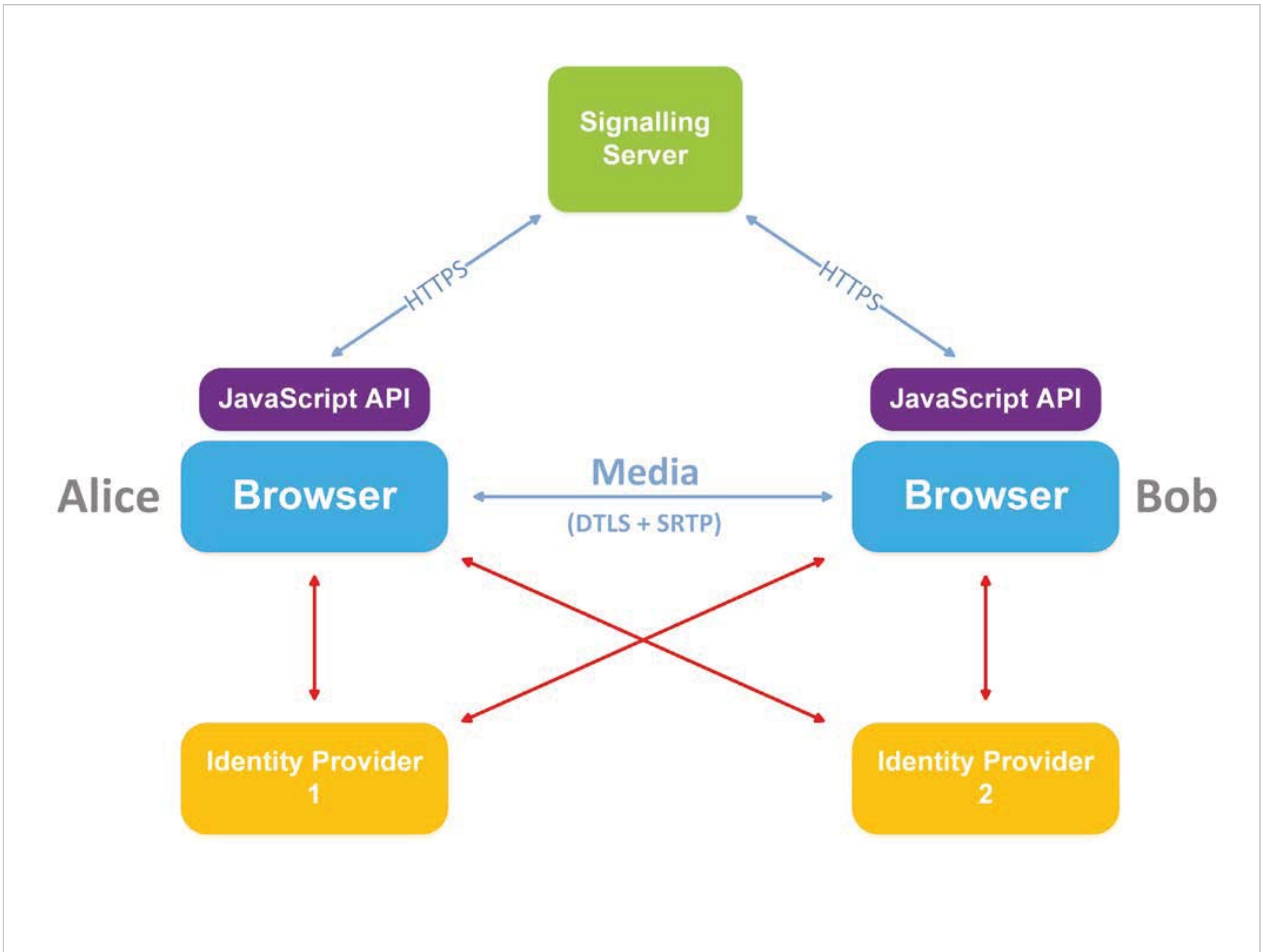

Figure 6. A call with an identity-provider-based identity [25]

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