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CHALLENGES OF "VoIP" COMMUNICATION SYSTEMS FOR AIR TRAFFIC MANAGEMENT

ABSTRACT

Today's dense air traffic and the worldwide move to Future Air Navigation System (FANS) concepts demand a high level of modern and reliable Air Traffic Control (ATC) equipment to accommodate customer requirements now and in the future. The work tries to answer the questions that indicate the fact why a new VCS generation (Voice Communication System) based on VoIP (Voice over Internet Protocol) has some essential comparative advantages related to the conventional VCS. One of the key arguments featuring the VoIP technology is its low price and wide application in modern communications. Because of the fact of the PC-based HMI (Human Machine Interface) application, IP-VCS could easily be implemented in the new ATM data network infrastructure. In the future, the VoIP technology development and VoIP VCS will have to prove that they are ready to meet the requirements of more flexible, safer and cheaper way of air traffic management.

KEY WORDS

ATM (Air Traffic Management), VCS (Voice Communication System), VoIP (Voice over Internet Protocol)

1. INTRODUCTION

Today's dense air traffic and worldwide move to Future Air Navigation System (FANS) concepts demand high level of modern and reliable Air Traffic Control (ATC) equipment to accommodate customer requirements now and in the future.

The work tries to answer the questions that indicate the fact why a new VCS (Voice Communication System) generation, based on VoIP (Voice over Internet Protocol) has some essential comparative advantages in relation to the conventional VCS.

During the past years, voice/data convergence, where all communications are switched and transmitted together using a common networking architecture became more and more an actual fact due to the permanent integration improvement in Telecom technology and associated cost savings and potential new services that they can offer.

On the contrary, "Voice-on-the-LAN" techniques, such as Voice over IP (VoIP) allow for carrying packaged voice over the existing platform data networks.

Voice/data convergence has been technically driven by the technical improvement of Internet Protocol (IP) networks offering a fully distributed architecture.

These IP networks became the adopted solution for voice/data convergence, because IP is the standard for data exchange and users can easily add specific decentralized services for dedicated applications.

Moreover, Voice over IP (VoIP) technology allows extensive use of Commercial Off The Shelf (COTS) equipment leading to potential decrease of price of VCS products.

The following reasons explain today's interest in VoIP technology for ATM:

- Mature technology supported by OTS components and equipment;
- Integration of voice and data traffic offering potential new Air Traffic Services (ATS);
- Single common network infrastructure providing reductions in total cost of operation and maintenance (less equipment, better standardization, optimized logistics)

In ATM-oriented VCS domain, most of the implemented VCS are still traditional VCS which consist of PC-based touch screens for data control associated with audio control units directly wired to a centralized switch for voice control. And most of the VoIP-based VCS are still proposed today for training and simulation applications only.

However, EUROCONTROL (European Organization for Safety of Air Navigation) announced that

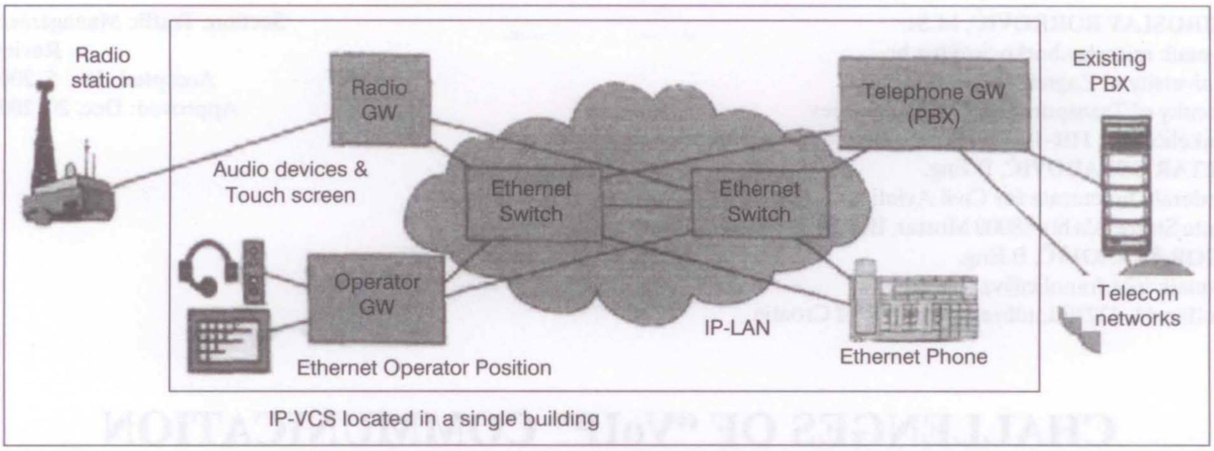

Figure 1 - Typical "stand-alone" IP-VCS architecture

IP-VCS should be implemented for operational services soon.

In ATM domain, before possibly adopting IP-VCS solution, the Air Navigation Service Providers (ANSPs) request to understand the real practical challenges that can be encountered when implementing this new technology.

2. IP-VCS ARCHITECTURE

The IP-VCS solutions are based on VoIP Local or Wide Area Network (LAN/WAN) associated with three types of gateways:

- COTS PBX Gateway - using H323 IP protocol - for telephone interface;
- dedicated radio Gateway for radio interface;
- dedicated position gateway for operator position.

Based on this equipment, two types of IP-VCS can be considered:

- a "stand-alone" IP-VCS architecture;
- an "Integrated ATC Platform network" IP-VCS architecture.

The "stand-alone" IP-VCS enables replacement of the traditional VCS and provides classical ports to external AG and GG voice communication networks (access to radios and access to public and private telephone networks).

The "Integrated ATC Platform Network" IP-VCS replaces not only one traditional VCS but also several VCS.

3. KEY ISSUES

3.1. Economic interest of IP-VCS implementation on ATC platform

The most obvious argument for IP-VCS is the replacement of two separate voice and data infrastructures by a single converged data network, and so, the potential use of a common Ethernet type LAN for both FDPS (Flight Data Processing System)/RDPS (Radar Display Processing System) and VCS subsystems.

While this optimization seems nice in theory, in practice, for safety reasons and internal organization, even in new ATC infrastructures, most ANSPs would prefer to invest in separate wiring networks and people/skill sets for maintaining their various subsystems. Therefore, FDPS/RDPS and VCS should keep separate duplicated LAN, at least in the first stage.

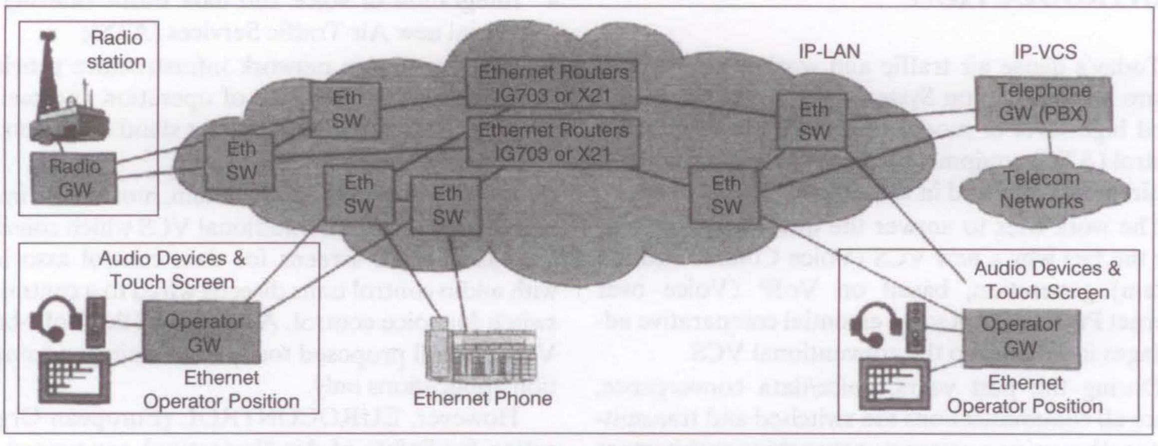

Figure 2 - Typical "integrated ATC Platform Network" IP-VCS architecture

Thus, it is difficult to justify the replacement of an existing VCS by an IP-VCS by just presenting the "network converge" argument.

Another argument is the potential distributed architecture of IP-VCS. While small ATC infrastructures (e. g. secondary airports) are less constrained by the pre-existing systems, the actual business challenge for IP-VCS should exist with the large ATC platforms.

Physical reconfiguration of ATC infrastructures - e. g. easy modification of locations of ATC workstations - could be the third argument for installing an IP-VCS system.

Knowing that the price is the key factor to enforce a new VCS and a new technology, there is a well--founded expectation from ANSPs that IP-VCS will be justified due to lower prices compared to the traditional VCS.

Today, it is too soon to know the actual market price of the future VCS. However, it can be imagined that, by using COTS equipment and when size of VCS to be installed is in favour of IP-VCS (e. g. implementation of large ATC platform), IP-VCS should be more competitive than a traditional VCS.

3.2. Specific ANSPs investment for IP-VCS migration

Indeed, while IP-VCS could be easily implemented in new ATC infrastructure (as long as procurement price remains competitive), it could be difficult to sell IP-VCS to replace the existing installation for the following reasons:

First, if the current VCS has adequate functions and capacity, and end-users have perfect knowledge of how to use and maintain it (and also master its weaknesses), why settle for a brand-new IP-VCS that has so different features (operational functions, configuration, architecture, installation).

Second, switching to IP-VCS may represent a major infrastructure upgrade that requires re-wiring, new LAN, new cabling, knowing that sometimes the use of new LAN is not possible because of the remote locations of some positions (existing cables located under runways).

Third, ANSPs have to invest in training controllers, supervisors and technicians not only on the use and configuration of the new VCS but also on theoretical courses on IP, voice on LAN, routers which are new components in VCS domain.

3.3. Reliability and availability at competitive costs

3.3.1. Last resort operation system

In Air Traffic Management domain, any ANSP perfectly agrees that AG (Air-Ground) and GG (Ground-Ground) voice communications represent the most critical application. VCS controlling AG and GG voice communications are used as "Last resort operation" system.

When data management systems fail or ATC workstations shut down, ATC controllers use the telephone and radio communications to continue their mission: "keep the sky safety".

Similarly, ANSP technical managers / system administrators never have to reset their VCS, but sometimes they need to reboot their ATC data servers and workstations and have to perform periodic preventive and corrective maintenance on them.

Therefore, before ANSPs can seriously consider implementing IP-VCS system, they need to understand the reliability and availability of such a vital system.

3.3.2. Redundancy

One way to achieve high VCS system availability is to install redundant and "fault-tolerant" system components. Redundancy provides "fault-tolerance" because if a component fails, the hot spare will take over without any loss of service.

"Fault tolerance" can be achieved through the use of hot-plug-in components. Even if a component fails, a truly reliable product will allow the technician to replace the faulty unit without powering down the entire system. These types of fault tolerant and redundant equipment techniques are implemented in today's VCS.

3.4. Operational Functions

3.4.1. A large range of VCS functions

From several decades, traditional digital VCS have been improving their operational functions by adding new features which are implemented in powerful centralized and duplicated processing units.

Probably no ATC controller uses all of the functions available in their current VCS, but each functional organization within an ATC structure (e. g. ACC, APP, TWR) needs to use different sets of features.

For both reliability and economic reasons, it is commonly verified that new products with new architecture - this is the case for IP-VCS - are implemented in their first versions with a reduced number of operational functions and with some capacity restrictions.

3.4.2. Limited range of functions in IP-VCS

Therefore, IP-VCS suppliers could decide to only implement the basic AG/GG operational functions that are mandatory, such as DA (Direct Access) and IDA (Indirect Access) telephone calls.

However, this possible decision unfortunately would cause many ANSPs to wonder why they had to switch on the new VCS product which may involve risks and constraints while providing fewer functions than with their existing VCS.

3.5. Remote installation limitations

Most of the traditional VCS fitted with digital 2B+D/144 Kbps type interfaces or analogue CB interfaces, allow ANSPs to locate operator positions and traditional telephone sets as far as one kilometre (and sometimes more) away from the digital VCS, using the existing copper cabling wired network.

It is important to point out that some traditional VCS fitted with 30B+D/2Mbps do not allow easy installing of remote positions and they need extra equipment, such as modem. Because they are standard Ethernet devices, Ethernet positions and phones are limited to 100 meters far from the hub/switch. This could be a limiting factor for widespread deployment of IP-VCS systems in large ATC platforms where TWR, APP and ACC rooms as well as secondary rooms (meteo, briefing) are all located in various buildings.

3.6. VCS reconfiguration and management system

With IP-VCS systems, there will be no concept of a physical port. Indeed, "VCS subscribers" to be managed will need to be associated with a particular "user name" or some other parameters, such as the IP address. An IP-VCS could be managed based upon uniquely defined user names. With such a system, an operator as "VCS subscriber" would have the same telephone number and access rights whatever the type of equipment used. In such a way the technical supervisor as "system administrator" would be able to globally manage every "VCS subscriber" from a central location.

Another potential solution could be to only manage each VCS subscriber based on their IP address. Managing VCS subscriber based on their IP address would require the use of static addresses. This could complicate the administration of the entire IP addressing scheme for common data and voice LAN used for multi-purpose applications.

3.7. VCS suppliers' credibility and experience

Information Technology (IT) networking staff do not have specific knowledge about Voice Systems (VCS, PBX, radios), and telephony technicians do not usually know much about data networks. This is one of the reasons why most ANSPs today employ separate staffs for operation of their ATC subsystems (FDPS/ /RDPS, VCS, radios, navaids, radars). It can be also noted that data network administrators have a different concept of system availability than voice system administrators.

Voice Communication Systems, and especially ATC-oriented VCS, must not be considered as just another network application that can be installed and maintained along with e-mail, web, and database programs.

VCS has its own rules, words, technology and safety requirements. As far as current VCS suppliers are concerned, they are obviously more comfortable with voice technology and understand the resiliency and high reliability needed for any VCS.

VCS suppliers have a long history of service, maintenance and support of their existing VCS, but it is going to take some time before they can offer the same level of expertise for IP-VCS solutions.

ATC system companies able to design today all the ATC subsystems and so mastering both data and voice processing, have a definitive advantage over other dedicated VCS suppliers or data network suppliers.

3.8. Non-blocking system

While LAN PBX may provide several Qualities of Service (QoS) with the use of priority and may punctually provide operational unavailability due to a number of simultaneous calls, VCS must provide, at any time, instantaneous voice connectivity with high voice quality. The system is "non-blocking", which means that it guarantees access to all communication channels by any operator at any time regardless of the system load.

Therefore, the users will never note the "busy" indication because of the insufficient system capacity.

3.9. LAN quality of service

Compared to most data applications, voice packets are much more susceptible to any kind of delay. These transmission impairments will be readily noticeable and result in degraded voice quality. Thus, while a pre-existing network may be acceptable for data transmission, it may not be adequate for sending voice packets.

How do ANSPs determine whether their existing LAN infrastructures provide acceptable quality of service for voice? This is not something that can be easily tested, since problems may only occur during the unusual or peak data traffic periods. Instead, ANSP technical managers need to consider how their networks will respond during such periods.

There is a perception that if average LAN use is sufficiently low (or conversely, there is an abundance of bandwidth), then voice quality will be acceptable. However, this is not necessarily true. It is in the nature of most IP data applications to burst to full capacity of a circuit, even for very short periods of time.

If voice packets happen to be transmitted during the same time period, contention for bandwidth will occur and some of the voice packets will be dropped or delayed.

ANSPs need to be able to determine how lightly loaded the LAN must be in order to ensure that voice packets do not get dropped when bandwidth contention occurs.

3.10. Voice quality

Indeed, Voice Quality (VQ) should be considered as the main issue in Voice Communication System. Voice and thus, Quality of Voice is a mandatory feature of any ATC-oriented VCS to get an accurate system able to meet ANSPs expectations related to Air Traffic Safety. Voice Quality is basically a way of describing and evaluating speech fidelity, intelligibility and characteristics of the analogue audio signal, but finally, VQ represents the level of ability to transmit the right and immediate audio message between controllers and pilots (radio communications).

Technically speaking, within an ATC-oriented VCS, VQ can be defined as the qualitative and quantitative measurement of the audio quality of an AG or GG voice communication. VQ is composed of three factors: clarity, delay and echo. VQ may suffer because of the following main issues:

- Delays (times for digitalization, packeting, transmission, routing delay and buffering);
- Echo;
- Packet loss;
- Voice compression.

3.10.1. Delays

The main weakness of any packaged voice stream, in comparison with classical digital PCM voice signal, is delay. Once a packet takes longer than 100 - 200 milliseconds to travel to its location, voice quality starts to become unacceptable.

And delay in VCS will be added to the delays in other equipment within the whole voice communication segment, e. g. AG voice communication between controller and pilot goes through VCS, transmission network (using equipment such as microwaves, multiplexers) and radio equipment.

Human factors research has shown that most people greatly dislike long transmission delays in voice communications. Subjectively, too much latency makes it difficult to carry on a very short and effective dialog which is typically required in ATC domain.

3.10.2. Echo

Echo is caused by an electrical mismatch between analogue audio devices and transmission media in a portion of the network called "tail circuit". Echo becomes a problem in most voice over packet networks because the round-trip delay through network is almost always greater than 50 ms - the threshold of human perception.

A special type of echo, named "AG Side-tone" is required in VCS at operator position level in order to enable controllers to hear his/her own voice in the headset / handset ear-piece while speaking to pilots (AG radio communications).

3.10.3. Packet loss

Packet loss can be caused by congestion, router changes as result of faulty network line and sometimes by a too long delay in the network. Lost or dropped packets can be a significant problem affecting voice quality.

Because IP networks do not guarantee packet delivery, under peak loads and congestion, voice frames will normally be dropped in a manner similar to data frames. Most data frames, however, are not time-sensitive and dropped packets can be recovered through the process of retransmission by the TCP end-to-end protocol.

3.10.4. Voice compression

A user's voice signal must be sampled and converted to a digital bit stream before it can be transmitted over the network. The use of more compression generally results in worse voice quality, and adds more delay due to the additional processing required.

For instance, not less than 16 Kbps compression is required to reach a "3-ms" delay. Because of this trade-off between voice quality versus bandwidth savings due to compression, there are different ITU CODEC standards that may be used.

For example, standards such as G. 711 are designed to code and decode voice at an uncompressed rate of 64 Kbps, but with very high quality and minimal delay.

Other CODEC such as G. 723 can compress voice down to 6 Kbps, but are more computationally intensive, provide a delay of up to 30 ms for compression/decompression processing, and the resulting speech quality may not sound as good.

The best solution might be to use a CODEC capable of compression, but only compress on a call-by-call basis. For example, a call to another local controller on the same LAN may only need to use a G. 711 CODEC, but a call to a remote subscriber (remote controller in another site or pilot) across a WAN may need the added compression of a G. 723 CODEC.

In this case, delays depend of the type of calls.

4. CONCLUSION

Today's dense air traffic and worldwide move to Future Air Navigation System (FANS) concepts demand high level of modern and reliable Air Traffic Control (ATC) equipment to accommodate customer requirements now and in the future.

The work tries to answer the questions that indicate the fact of why a new VCS generation (Voice Communication System), based on VoIP (Voice over Internet Protocol), has some essential comparative advantages in relation to the conventional VCS.

The International Air Transport Association (IATA) and world traffic policy demand more radical changes in terms of reducing the prices of air traffic management services.

One of the key argument favouring the VoIP technology is its low price and wide application in modern communication. The mass world investments, namely, in this technology give the real expectations that IP-VCS will be stimulated and justified because of the low prices in comparison to the traditional VCS. However, it is still too early to talk about the actual market price, but it is supposed that the future VCS generation should be more competitive than the conventional one, particularly if the fact that the IP-VCS could be as reliable and available as the traditional one is taken into account.

For both reliability and economic reasons, it is commonly verified that new products with new architecture, which is the case for IP-VCS, are implemented in their first versions with a reduced number of operational functions and with some capacity restrictions.

Therefore, IP-VCS suppliers could decide to only implement the basic AG/GG (Air Ground / Ground Ground) operational functions that are mandatory, such as DA (Direct Access) and IDA (Indirect Access) telephone calls, but not complete functions, especially in radio communication, that have already been comprised in the conventional VCS.

Because of the fact of PC-based HMI (Human Machine Interface) application, IP-VCS could easily be implemented in new ATM data network infrastructure, but because of the predescribed restrictions, it would be very difficult to believe that IP-VCS could already replace the existing conventional VCS at this level of development.

Air traffic regularity and safety must not be compromised with the systems which have less availability than today's, although they are much cheaper.

In other words, VoIP technology development and VoIP VCS will have to prove in the near future that they are ready to meet the requirements of more flexible, safer and cheaper way of air traffic management.

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SAŽETAK

IZAZOVI PRIMJENE VOIP SUSTAVA GOVORNIH KOMUNIKACIJA U UPRAVLJANJU ZRAČNIM PROMETOM

Sadašnji trend rasta zračnog prometa te svjetska tehnološka kretanja prema konceptima budućega sustava zrakoplovne navigacije FANS zahtijevaju visoko pouzdane i moderne sustave u centrima kontrole zračnog prometa koji bi udovoljili strogim zahtjevima davatelja takvih usluga, kako sada, tako i u budućnosti. Ovim se radom pokušava dati odgovor na pitanja koja ukazuju na činjenicu zašto nova generacija VCS-a (Voice Communication System), temeljena na VoIP-u (Voice over Internet Protocol), ima neke bitne komparativne prednosti u odnosu na konvencionalni VCS. Jedan od ključnih argumenata koji favoriziraju VoIP tehnologiju je njena niska cijena i masovna primjena u modernim komunikacijama. Zbog činjenice primjene PC baziranih HMI-a, IP-VCS bi se mogao jednostavno ugraditi u novu ATM podatkovnu umreženu infrastrukturu. Razvoj VoIP tehnologije, a time i VoIP sustav govornih komunikacija će u bliskoj budućnosti morati dokazati da je spreman udovoljiti zahtjevima fleksibilnog, sigurnijeg i jeftinijeg načina upravljanja zračnim prometom.

KLJUČNE RIJEČI

upravljanje zračnim prometom, sustav govornih komunikacija, sustav govornih komunikacija preko Internet protokola

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