Wireless technologies Pre-Screening: Evaluation for avionics

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Abstract—**this paper presents the recent results of SCA project (Communication Systems for Avionics), on the evaluation of the means of communication able to ensure airlines companies needs on airport platforms.**

Exchange of AOC/AAC (Aeronautical Operational Control/ Aeronautical Administrative Communication) messages between aircrafts and their airline companies is required on the ground. The concept of technology readiness level is presented to lead to the best choice of wireless technology. Evaluation of each technology is described for various scenarios of aircraft location within the airport.

I. Introduction

The technical innovating character of the project lies in the use of last generations all-IP communication means (Wifi, UMTS, HSDPA 3G+, WiMax), and in the introduction of these IP communication means into the avionic domain (cockpit) in order to integrate aircrafts directly into the data-processing network of the airline company.

The system considered by SCA project is based on the use of Internet, via wireless communication means, instead of the aeronautical private network for the exchange of AOC/AAC messages (ACARS) between the avionics domain and the ground system.

The use of Internet via a high speed wireless access (cellular GPRS, HSDPA 3G+, UMTS, Wifi, Wimax…) has the double advantage of increasing the capacity of communication (number of offered services) of the planes (ground coverage more important than current network VHF ACARS) while reducing communication costs and the obstruction of VHF spectrum [1].

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The communication via Internet makes it possible to secure (authentication, encryption) communications between planes and the ground system of airline companies on the basis of current standards of security (VPN, IPsec), unlike ACARS communications which do not support security services.

Wireless technology has shown rapid progress and has been used widely to help people doing their daily activities. A few decades ago, communication was limited to voice, but now it has been developed so that people were able to transmit data, text and video during their communications.

The development from audio to video mobile communications was designated as development from 1G to 3G [2], [3], and [7].

This paper aims at investigating technology readiness level of current wireless and mobile technologies for avionics applications. To organize the presentation of the results, the paper is divided into four sections. Following the introduction, an overview of wireless technology is given. In the third section, the concept of technology readiness level is presented, and applied for each communication mean. Fourth section elaborates the relationship between technology readiness level and effective adoption or not of the technology.

II. Overview of wireless technologies

Users are using wireless data communications in a wide range of applications, including e-mail, game downloads, instant messaging, ringtones, and video as well as enterprise applications such as group collaboration, enterprise resource planning, customer relationship management, and database access. This simultaneous adoption by both consumers for entertainment-related services and businesses to enhance productivity increases the potential return-on-investment for wireless operators.

A number of important factors are accelerating adoption of wireless data. These include increased user awareness, innovative feature phones, powerful smartphones, and global coverage. But two factors stand out: network capability and applications. Technologies such as GSM, WCDMA and HSPA (High Speed Packet Access) provide the capability to support a wide range of applications, including standard networking applications as well as those designed for wireless. Meanwhile, content suppliers are optimizing their applications, or in many cases developing entirely new applications and content, to target the needs and desires of mobile users.

EDGE is an official 3G cellular technology that can be deployed within an operator's existing 850, 900, 1,800,

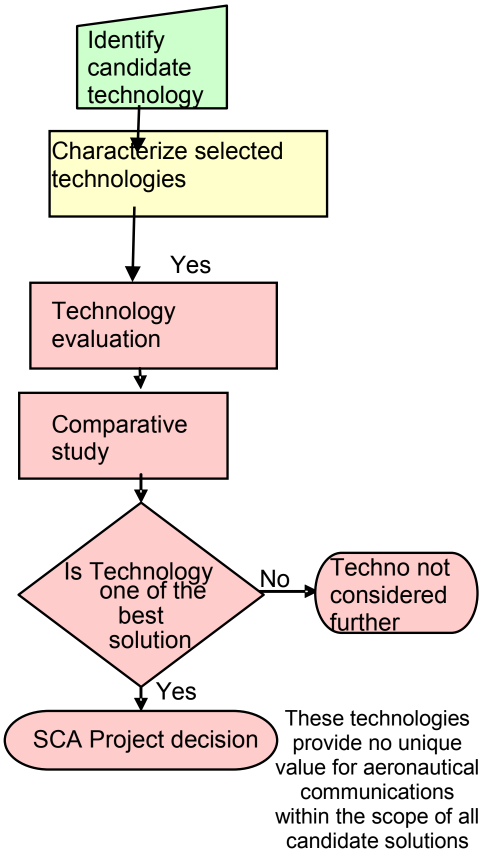

Figure 1 Technology Investigation

Detailed Technology Analysis and Selections

and 1,900 MHz spectrum bands. A powerful enhancement to GSM/GPRS networks, EDGE increases data rates by a factor of three over GPRS and doubles data capacity using the same portion of an operator's valuable spectrum.
High Speed Downlink Packet Access is a tremendous performance upgrade for packet data that delivers peak theoretical rates of 14 Mbps. user-achievable throughput rates in initial deployments are well over 1 Mbps, three times faster than Release 99 data, and will increase over time with enhanced terminals and network capabilities.

Like GSM/UMTS, WiMAX is not a single technology; it's a family of interoperable technologies. The original specification, IEEE 802.16, was completed in 2001 and intended primarily for telecom backhaul applications in point-to-point line-of-sight configurations using spectrum above 10 GHz. This original version of IEEE 802.16 uses a radio interface based on a single-carrier waveform [4] and [11].
WiFi is a commercial brand originally licensed by the WiFi Alliance to describe the underlying technology of wireless local area networks (WLAN) based on the IEEE 802.11 specifications [2]. Even if many variants of 802.11 technologies exist, some characteristics are unchanged:

- All of them are working in unlicensed bands (2,4 GHz or 5.1 GHz).
- Most of them do not support mobility (except for 802.11f and 802.11n).
- Short coverage (hundred of meters).

Figure 1 presents the diagram and the process of technology investigation, which allows identifying and selected the best solution for avionics. Each step of selection is required to show the ability of various technologies to satisfy the SCA needed services.
Various technologies (cellular, 802.11x, 802.16x, Wpan, Satcom…) are candidate for SCA project. Note that SCA scoop consists in providing the best quality of service between airlines companies and aircraft, and it will be applied within airport zone. In the following parts Wlan (802.11x) and Wman (802.16x, cellular) are presented.

III. Technology Readiness Level

Various models have been developed to explain how innovation or technology is adopted by users and how number of users increases from time to time. These models provide an indication of the technical maturity of the proposed technology [4].
The ability of adopted technology consists in satisfying the required bandwidth for each aircraft type (say A, B, and C). The table 1 presents the required bandwidth for aircrafts in various flight phases.

In the following part, the level of maturity for each wireless technology is presented.
This study is based on the technical characteristics and standards maturity. The objective is to evaluate technologies that provide best TRL.

A. Maturity level

Technologies Deployment:

Nearly every GSM network in the world today supports GSM data service (GPRS), making it the most broadly available IP-based wireless data service ever deployed. The GSM EDGE feature is another success story. As of September 2006, more than 239 operators in 121 countries around the world were using, EDGE has reached critical mass in terms of coverage of population, geography, infrastructure, and devices.

	Required Bandwidth (kbits/s)							
Aircraft	Pre-flight		Flight		Gate		Hangar	
A	50	115	300	810	256	540	0	4700
B	50	115	170	600	315	600	0	4700
C	50	115	80	300	210	720	0	4700
	Nominal	Maximal	Nominal	Maximal	Nominal	Maximal	Nominal	Maximal

Table 1: SCA bandwidth requirements

Today, GSM operators with EDGE have over half a billion potential customers within their networks. Because of the very low incremental cost of including EDGE capability in GSM network deployment, virtually all new GSM infrastructure deployments are also EDGE capable and nearly all new mid- to high-level GSM devices include EDGE radio technology.

Meanwhile, UMTS has established itself globally. Nearly all WCDMA handsets are also GSM handsets so WCDMA users can access the wide base of GSM networks and services [4], [6].

There are now nearly 75 million UMTS customers worldwide across 135 commercial networks. Fifty-one operators in 33 countries are offering HSDPA services, and an additional 54 operators have committed to the technology. It is likely that most UMTS operators will deploy HSDPA for two main reasons: one, the incremental cost of HSDPA is relatively low; and two, HSDPA makes such efficient use of spectrum for data that it results in a much lower overall cost per megabyte of delivered data.

Security:

The security functions of UMTS/ HSDPA are based on what was implemented in GSM. Some of the security functions have been added and some existing has been improved. Encryption algorithm is stronger and included in base station (NODE-B) to radio network controller (RNC) interface. The application of authentication algorithms is stricter and subscriber confidentially is tighter.

The most common wireless encryption standard, Wired Equivalent Privacy or WEP, has been shown to be easily breakable even when correctly configured. Wi-Fi Protected Access (WPA and WPA2), which began shipping in 2003, aims to solve this problem and is now available on most products. Wi-Fi Access Points typically default to an "open" (encryption-free) mode.

The level of security for wireless technologies (cellular, Wi-Fi, Wimax) is guaranteed to costumers. Various algorithms are used at several steps of information processing..

Device and component:

In the case of cellular networks, the components are available in the market for 3G/3G+ generations. In the other hand, the components for a new standard such as LTE (Long term evolution) require various tests to validate the technology maturity. The limit of our study consists in the ability of UMTS/HSPA+ standards to deliver a high speed throughput.

The maturity of components and devices is limited to 802.11x for wireless standards as Wi-fi and Wimax. The 802.16x components require validation tests.

In the next section technical characteristics associated to each candidate technology is considered. They are composed of throughput, range, spectral efficiency, latency and power consumption.

Standard	GPRS	EDGE	UMTS	HSPDA
Name	2.5G	2.75G	3G	3G+
Frequency	900/ 1800 MHz	900/ 1800 MHz	900/ 2000 MHz	900/ 2000 MHz
Max Throughpu t	115 Kbits/s	384 Kbits/s	2 Mbits/s	14 Mbits/s
Real Throughpu t	56 Kbit/s	177 Kbits/s	384 Kbits/s	1.8 Mbits/s
range	1 to 35 km.	1 to 35 km.	<10km	<10km
Qos (Quality of service)	Audio/ data	Audio/ data, WAP.	Audio, data, video	Audio, data, video …
Bandwidth	200KHz	200KHz	5MHz	5MHz

Table 2: standards characteristics

B. Technical characteristics

In this part, technologies technical ability to meet the needs of Airline Companies is considered.

Throughput:

Table 2 presents technical characteristics of cellular standards. It shows that HSDPA provides a high throughput compared to others systems. The best quality of service is achieved by 3G/3G+ families [2].

Spectral efficiency

High spectral efficiency is often desirable but it comes at a price, however. It generally implies greater complexity for both user and base station equipment. Complexity can arise from increased number of calculations performed to process signals or from additional radio components. Hence, operators and resellers must balance market needs against network and equipment costs.
In the case of mature technologies groups, HSDPA shows the higher value of spectral efficiency (see Fig.1). Beyond HSDPA, 3GPP LTE will also result in further gains in spectral efficiency, with spectral efficiency two to three times that of Release 6 HSPA.

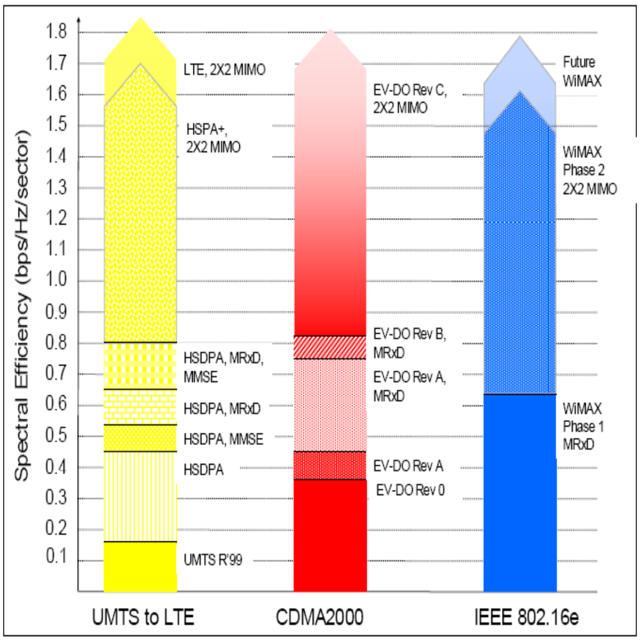

Figure 2: Spectral efficiency for Wireless technologies

3GPP standards bodies are still finalizing HSPA+ details, but if all optimizations under consideration are implemented, HSPA+ spectral efficiency could reach within 10% of LTE spectral efficiency in 5 MHz channels.

Latency:

Just as important as throughput is network latency: defined as the round-trip time it takes data to cross the network. Each successive data technology from GPRS forward reduces latency, with HSDPA having latency as low as 70 msec. HSUPA (High Speed Uplink Packet Access) brings latency down even further, as will 3GPP LTE [13]. Ongoing improvements in each technology mean all these values will go down as vendors and operators fine-tune their systems. Figure 3 shows the latency of different 3GPP technologies.

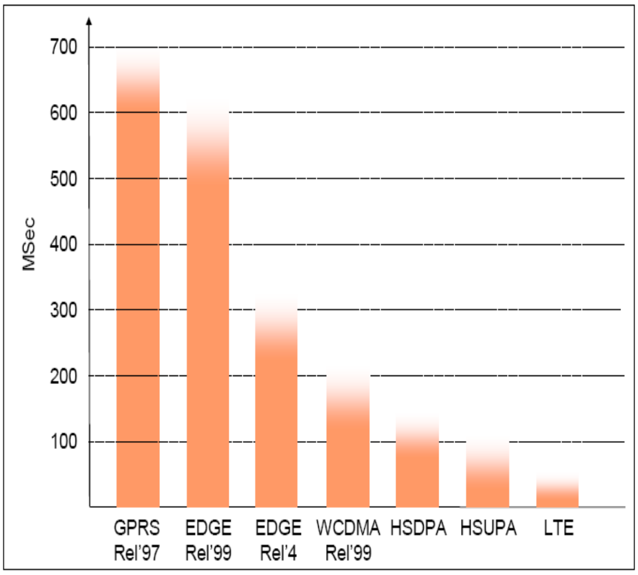

Figure 3: Latency of wireless technology

The values shown above reflect measurements in commercial networks. Some vendors have reported significantly lower values in networks using their equipment, such as 150 msec for EDGE and 70 msec for HSDPA.
The HSDPA evolution conducts to LTE technology, presenting a lower latency [4], [11].

Power consumption

Figure 4 shows a comparison of the peak mobile power dissipation while transmitting for the considered technologies. The values include both digital processing and RF elements. The HSDPA components require 2.5W to operate correctly, which is high in comparison to other technology as GSM family. A mobile device that provides high speed data requires greater computing power and greater RF power consumption, resulting in shorter battery life.
The contribution to the power consumption from the RF circuitry is much lower (typically 80 to 100 mW) and varies less versus wireless technologies.

The following section describes the last step of technology investigation diagram. The context of application is envisaged both for hub airport and regional airport. The best technology is evaluated through its score for different flight phase in the airport (gate, taxiway, hangar...).

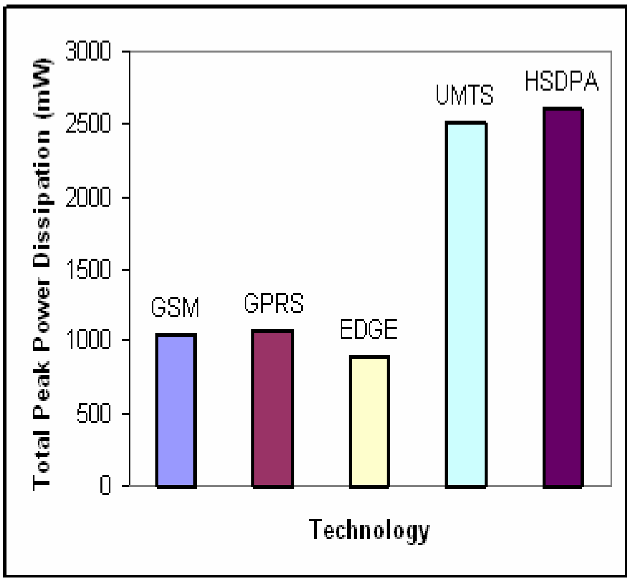

Figure 4: Power consumption

IV. WIRELESS USE CASE

For each standard, many factors are taken into account as: antenna design, BS (base station) or access point placement, interferences (multi-path, Doppler…). This works will allow to confirm whether or nor a given technology needs to be tested or is of interest.

Phase	Hangar	Hub Airport				Regional Airport			
		Landing/ take off	Taxiway	Parking	Gate	Landing/ take off	Taxiway	Parking	Gate
LASER	0	0	0	0	0	0	0	0	0
HYPER FREQU-ENCY	0	0	0	0	1	0	0	0	0
WiFi	3	0	1	2	3	0	0	1	1
Cellular Networks	1	1	2	3	3	1	2	3	3
Wimax	1	1	2	3	3	0	0	0	0

Table 3: Technologies use case evaluation

For each use case, technology evaluation is done thanks to the following criteria and scores:

- Impossible to use or unavailable → 0
- Low pertinence → 1
- Medium→ 2
- High→ 3

LASER:

This technology requires a high directivity. If one of the two antennas (emitter or receiver) gets unfocused, the link is broken. Pointing accuracy is around few degrees. The high sensitivity of LASER implies the unavaibility for several flight phases.

Hyper frequency:

Microwave based technologies can be used only if the airborne is grounded.
This technology can be used with antennas at the gate / aircraft door interface. But pointing accuracy would be an issue. Important attenuation is also a serious problem for technology deployment.

WiFi:

WiFi standards 802.11a-b-g do not support mobility. Furthermore, limited coverage implies installation of a high number of Access Points for efficient utilisation on the taxiway, which would be costly. It will remain the case with 802.11n since this standard should highly enhance indoor performances but less outdoor performances in terms of coverage.

Cellular Networks:

Cellular networks have an extended coverage, so it is possible to initiate data transmission on the runways during taxiing phases. No special regulation exists for aeronautical purpose. Aircraft users shall follow ITU regulation, which authorises only terrestrial use. This technology has the ability to operate for different flight phase, unlike others standards.

Wimax:

WiMax networks have an extended coverage, so it is possible to initiate data transmission on the runway during landing and taxiing phases. No special regulation exists yet for aeronautical purpose. In the case of hub airport, Wimax can provide various services with high throughput.

The comparative step (see figure 1) of technologies leads to the best solution choice. Required conditions for proposed solution are a good TRL (technology readiness level) and technical characteristics.
Currently, two standards satisfy these conditions: Wi-Fi (WLAN), and HSDPA (cellular networks).

V. CONCLUSION

* For ground applications in hub airport but also in regional airport, cellular technology is a good solution for the main ground phases (taxiing, parking and gate phases) as it is already largely deployed.

* WiFi is the best solution for hangar maintenance phase (especially MiMo WiFi) but is also candidate for gate phase in hub airport when available.

* WiMax is less mature technology but shows good potential to enhance performances of cellular and WiFi respectively in the future.

* WPAN Microwave and laser technologies seem to be inefficient for an aeronautical Datalink purpose.

This analysis shows that all these technologies are not competitors but complementary. The best solution is to develop a communication system implementing several of these technologies (at least Cellular and WiFi in same packaging).

An interesting perspective would be the studying of hard handover techniques to implement and use several technologies at a time (ex: WiFi, HSDPA).

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