Information technology at the Olympic Games

Boris Sakac
Advisor to the International Olympic Committee in Games Technologies and ORIS (Olympic Results and Information Services) Project Director, General Manager of ADASIT IT Consultants Ltd, Zagreb, Croatia.

Abstract

The Olympic Games are the biggest sports event worldwide. At the same time their computerized support is the most complex application of Information Technology in sports. Today there is not a single aspect of the Olympic Games, which is not supported by computer systems. The most exposed and most visible applications are sport results processing and worldwide information diffusion, however, there is a large number of other areas where computers play an important role, from events schedule planning and maintenance to the support of the Games logistics (participants' accreditation, arrival/departure, transportation, accommodation, catering, medical assistance, uniforms distribution, etc.). Software supporting all these applications consists of millions of lines of code. A huge hardware network of more than 10,000 computers and 4,000 printers attached to 900 servers (data from Athens 2004) has to be installed within a few weeks. The team which operates and supports these computer systems consists of 300–400 professionals coming from more than 30 countries and are joined by more than 2,500 local volunteers. Clearly, their opportunities to practice and work together before the Games are very limited. And all of this in an environment where there is an absolute deadline and just one chance to get it right. This paper describes the key functions of the Olympic Games computerized support, how different systems are designed and implemented and the challenges that are facing future Games organizers and their Information Technology providers.

Keywords: timing and scoring, results processing, information diffusion, scoreboards and video-boards, CIS-TV commentators system, press agencies, internet, print distribution, accreditation, transportation, uniforms, medical, volunteers, network, interfaces, security, back-up, testing, ORIS

1 Introduction

Computers are used from the first step in the Olympic Games preparations as a tool for venue construction planning and follow up, for Games event schedule planning, for the ordering of required sports and technology equipment, for ticket

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sales, for planning personnel who will organize the games, for defining registration and the selection of volunteers, etc.

All of these tasks, as well as detailed planning of arrivals/departures, transportation, accommodation and catering for sport delegations, media and officials are supported with appropriate software solutions.

Before the Olympic Games actually begin, data concerning all participants – athletes, media reporting from the Games, officials and games organizers – are entered into the so called "registration data bases" which are used for different purposes, mainly in the logistics areas. One of those is the "accreditation process" during which participants receive credentials (accreditation badge) that allows them to access those zones of venues, media centres and accommodation sites that correspond to their function.

Once the Games begin, computers installed at all venues process the data that are acquired from electronic interfaces with timing, scoring and the judges' devices. Within hundredths of a second, results are processed and disseminated to the huge network of computers for display on scoreboards, insertion into the live TV signal, and for the update of the Internet servers hosting Olympic web sites, relaying them in real time to servers of the major News Press Agencies, etc.

At the same time, results are updated in the Games Information data base, from where media and other users can retrieve them from the so called "INFO" work stations installed at all venues, media centres and accommodation sites. This system is also a basic source of information about athletes, their past achievements, flash quotes and a number of other data prepared and maintained by the Olympic News Service (ONS).

It is true that most of these computer applications are also used in other areas of human activities, and at some other sport events. But what makes implementing them at the Olympic Games so different and unique?

- quite a few of these computer applications are extremely "mission critical", have an absolute deadline, have worldwide visibility and have no "second chance" if something were to go wrong
- competitions at the Summer Olympic Games are organized into 38 sport disciplines at 40–50 venues, and during each of 16 days results systems support must be provided to an average of 25 of them at the same time (in parallel)
- it is difficult to find any other situation where such a large quantity of equipment – more than 10,500 workstations, 4,000 printers, 900 servers, 300 routers and 2,000 switches – located at almost 100 different locations – must be installed in a few weeks; and once the Games begin all of this hardware has to function perfectly
- there is a number of different hardware and software interfaces between computers that connect the Games with the "external world" – with timing and scoring equipment, with the computers of TV broadcasters, News Press Agencies, major Newspapers, Internet providers, etc. – and the time available to install and test these interfaces is extremely short
- all applications require a very simple and "easy to understand" users' interface, because most of the people who use or operate them have a very limited time to become familiar with them

- it is a considerable challenge to coordinate and manage the team of almost 3,000 people who operate Games IT and who come from a large number of different companies, countries and cultures, who speak different languages and who are working together for the first time.

2 Olympic Games Information Technology milestones

Computers were used for the first time at the 1960 Winter Olympic Games (WOG) held in Squaw Valley (USA) and the Summer Olympic Games (OG) held in Rome (Italy) where tabulating machines were used to calculate results at some of the events [1]. Since then, as in all other areas, the role of computers has become more and more important, following the dramatic progress in related technologies and in the computer literacy of users. A short history of the computer support at the Olympic Games follows:

- at the 1964 Innsbruck (Austria) WOG and Tokyo (Japan) OG on-line terminals were used for the first time to collect results data, and results were printed at each venue
- at the 1972 Munich (Germany) OG media used a computerized system as a source of information about athletes and historical results for the first time
- at the 1976 Montreal (Canada) OG and Innsbruck (Austria) WOG the first mainframe-based systems with an attached network of terminals supported the results processing/distribution from all venues and supported the accreditation of the participants
- at the 1980 Moscow (Soviet Union) OG the first "self-service" information retrieval terminals were installed in media centres [1]
- at the 1984 Sarajevo (Yugoslavia) WOG the software architecture that forms the basis of today's Results Systems was first introduced. For the first time Timing and Scoring equipment from all venues were electronically interfaced with the Olympic Games computer system. The first e-mail application was available for all participants
- at the 1984 Los Angeles (USA) OG the first massive Information retrieval system with more than 1,700 terminals was installed. A complete set of back-office applications, including ticket sales, was installed on minicomputers and some of them on PCs
- at the 1988 Seoul (South Korea) OG the first de-centralized systems were used for the results processing at the venues
- at the 1992 Albertville (France) WOG, PCs were widely used for the results system interfaces for the first time. The TV commentator information system function was available remotely, and was used from TV studios hundreds of kilometres away
- at the 1992 Barcelona (Spain) OG an interactive touch screen Radio and TV Commentator Information System (CIS) was implemented for the first time
- at the 1996 Atlanta (USA) OG the first official Olympic web site on the World Wide Web was available [1]

- at the 1998 Nagano (Japan) WOG the first implementation of a Traffic Management System based on sensors installed above roads enabled real time traffic information, the adjustment of traffic signals and relayed information to drivers through interactive GPS-based equipment to inform them of the fastest way to their chosen destination [1]. Computer driven Video-On-Demand kiosks were installed at media centres, allowing the viewer to choose whatever video footage he wished to view from the Games
- at the 2000 Sydney (Australia) OG the last system implemented on mainframes worked perfectly. The huge number of visitors to the official web site was efficiently handled
- at the 2002 Salt Lake City (USA) WOG a completely new computer systems architecture was implemented, based on a network of servers that completely replaced mainframe-based systems [2]
- at the 2004 Athens (Greece) OG advanced timing and scoring technologies (such as transponders and DGPS) were fully integrated with computer driven Results Systems for the first time [3]
- at the 2006 Torino (Italy) WOG an integrated "Internet Data Feed" (IDF) provided all real time information electronically to different Internet providers and Broadcasting Companies [2]. A new sophisticated computer driven Judging System that combined interactive touch screen entry stations for judges with the video replay system was implemented at the Figure Skating competitions for the first time [3].

3 Software applications supporting Olympic Games

People and companies working at the Games Information Technology support usually break down software applications into three major groups: Results Systems, Information Diffusion System and Games Management Systems.

3.1 Results systems

Everything that happens during competitions at the Olympic Games generates a result – a rate of speed, an elapsed time, a ranking and a score. These results need to be collected, processed and distributed in real time to electronic scoreboards, TV graphics equipment and TV Commentators' monitors and relayed instantly to the world.

As mentioned in the introduction, results processing is the most visible and publicly exposed function of the Information Technology at the Olympic Games. Malfunctioning of the On Venue Results (OVR) system could cause interruption, postponement or cancellation of events. Wrongly registered or miscalculated results could have unpleasant and undeserved consequences to athletes, and bring incorrigible discredit to the Games organizer and the organizations/people operating the result systems.

For this reason the design and implementation of OVR system is the most critical aspect of the Games IT support. All systems are designed in such a way

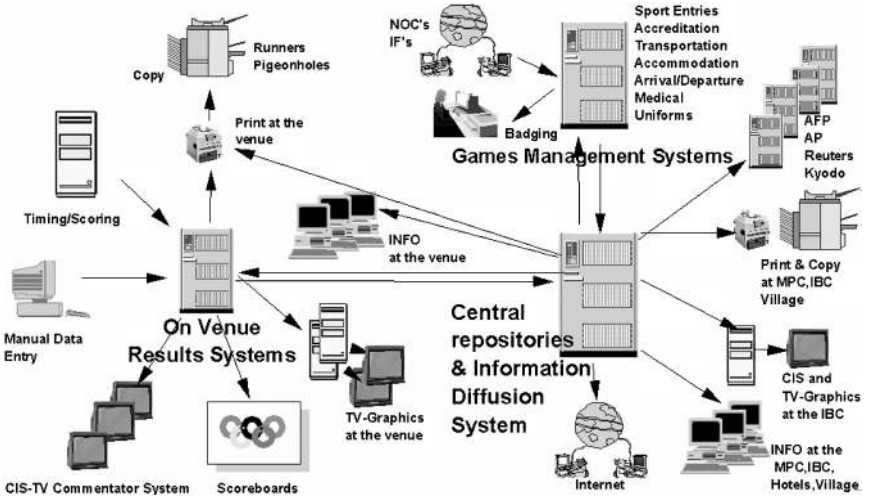

Figure 1: Systems overview.

that at least two completely independent systems are processing results in parallel. They do not share any resource, not even the power supply. In some sports where the competition could not resume if systems went down, a third independent system may even be used.

Another reason for the specific treatment of the Results System is the fact that live TV coverage strongly depends on the results service. Like most other large sports events, the Olympic Games are financed mostly from TV rights. TV Broadcasting companies are paying significant sums to the Games organizers in order to have exclusive right to broadcast Olympic competition in their countries.

In order to deliver attractive programs, these companies must provide their audiences with instant results and rankings. Who would be interested in watching the Swimming or Alpine Skiing events if the running time was not permanently displayed on the screen, or if the ranking at intermediate points and at the finish was not available instantly?

Some sports, such as Biathlon, have been transformed by the use of technology. As competitors start the race at different times, and in addition to the time achieved, a second criteria of precision in shooting determines results, live TV coverage was rather boring until the use of advanced technologies was implemented to electronically record times and shooting scores. Now, spectators know at any moment who is leading the race and how far behind other athletes are, and this sport has become one of the most televised winter sports.

3.1.1 Results acquisition

Providing audience with real time results would not be possible if computers that calculate results and rankings were not directly interfaced with timing, scoring

and judges' devices. A number of these interfaces are based on very advanced technologies.

In sports where the criteria for ranking is the time an athlete took to complete a fixed distance, time is measured with extremely precise instruments. If the athlete is competing alone at that time (e.g. Alpine Skiing) it is measured with photo cells. But when there are more athletes competing together, the time is measured either with video-finish devices, or with the use of transponders (chips weighing 5 g) attached to the athletes' shoes or equipment. In sports such as Athletics, Rowing or Canoeing where more competitors are competing at the same time, the specially designed video-finish camera at the finish line operate at a speed of 2,000 frames per second, and operators and officials are able to determine the result of each athlete/boat at the computer displays to which the video-finish camera is attached [3].

In swimming, where each swimmer is competing in a separate lane, the swimmer stops the timing system by hitting the touch pad at the finish line.

In Road and Track Cycling a tape switch, with two elements of an electronic circuit which are held several millimetres apart by an extruded plastic former, is laid out on the track or road surface, and when the front wheel of the bicycle goes across the tape, the timing system will recognize it.

When it is important to precisely locate an athlete or a team, such as in Sailing, location is identified by Differential Global Positioning System (DGPS) which permanently transmits information (accurate to 1 m) by radio signal to the results system computers on shore [3].

In sports where touches of opponents have to be recorded (such as Fencing or Taekwondo), scores are registered through sensors installed in the athletes' clothing or helmet.

In Artistic Gymnastics and Figure Skating, judges enter scores using touch screens. Software requires that they immediately judge each action. They are also supported with a sophisticated computerized video system that allows them to instantly replay a video recording of athletes' performance from any point.

Specially designed "Speed guns" are already used to measure the speed of the ball in Tennis and Beach Volleyball, or the shuttle in Badminton. In Tennis the so called "Hawk's eye" video system will be used to check whether a ball is "in" or "out".

In most of the "team" or "head to head" sports in which the actions to be recorded cannot be acquired by instruments or other equipment, data are entered manually, either by Judges and Referees, or by specially trained operators. In Judo, Taekwondo and Boxing, judges award points by pressing buttons, and points are awarded if more than the required number of judges press the same button within a fixed time frame.

For scoring in Shooting and Archery, special electronic targets have been developed, with accuracy of 1/10 of a point. In some disciplines the centre ring has a diameter of only 11 mm [3].

Most of these timing and scoring technologies were developed for use for the first time at the Olympic Games, but many were first tested at smaller competitions.

3.1.2 Results processing

Algorithms for results processing that rank athletes and teams based on their achievements are defined by rules set by the International Sport Federations for each sport. Software consisting of thousands of lines of code is developed to correctly process data acquired from the fields of play, and to present results in a number of different formats suitable for presentation at scoreboards, TV screens, printed reports, electronic messages, Internet, etc.

Programming of the so called "happy path", when everything works smoothly, when there are no ties or disqualifications or other exceptions is the easiest part of the job. However programming support for many types of exceptional situations that could occur is a much more complex task. How should several athletes, who achieved exactly the same time or score, be ranked, even when results have been measured with maximum accuracy? Should results of all other athletes be re-calculated if an athlete is disqualified after the event because of doping, and in what way? Under what conditions, should a new record be recognized?

In some cases, the International Sport Federation rules are able to define the necessary procedures for all possible scenarios, but in many instances this is not the case. Those responsible for preparing the software which must be capable of automatically coping with the foreseeable exceptional situations have to analyze not only previous cases at competitions in that sport, but also discuss with Federation officials other possible eventualities. In most cases the number of lines of code for handling these exceptions is several times greater than the routine processing of the regular situations.

In order to ensure that software will efficiently and accurately process results in real time, a major effort for those people involved in the preparation of Results System software is its testing. This is done not only by the companies that develop the software, but also by several independent testing teams. One of the last tests in this process is the so called "IOC Homologation Test", during which representatives of the International Sport Federations together with experts nominated by the International Olympic Committee and some media organizations test the results system for each sport extensively. By following previously prepared test scenarios and running many different test cases, they are able to check that the system correctly processes results in all predictable situations.

3.1.3 Result System outputs

The OVR system has to calculate results in thousandths of a second, and provide several outputs in parallel:

- for spectators at the venues, results are immediately displayed on the scoreboards or video boards
- for TV audiences, results are inserted in the live TV picture via computer driven video graphical generators operated by the TV companies. At the Olympic Games, TV broadcasters from several of the richer and bigger countries do not use the results graphics provided by the Games systems. They receive the "raw data"

from which they produce their own graphics, with text translated into their languages, and the results of their athletes highlighted
- for Radio and TV Commentators reporting live from the venue results are provided at the PCs with touch screens monitors (CIS system)
- for Competition management, Federation officials and written press journalists, the OVR System provides printed result reports
- at the same time processed results are relayed to the Central Repository, from where Information Diffusion System disseminate them to remote users at the other venues, Main Press and Broadcasting centres and the whole world.

3.2 Central Repository and information diffusion

All OVR systems are connected through the internal Olympic Games communications network to servers that are used as the Central Repository of the Games information. Results are stored in the data base which is also used for many other types of data.

Prior to the Games, the Organizing Committee Olympic News Service store historical information on results of previous Olympic Games and other major sport events, athletes' biographies and other interesting facts and figures in the Central Repository servers. Before the Athens 2004 Games, the ONS prepared and uploaded more then 50,000 pages of such information in English, French and Greek [2].

During the Games, the ONS stores different news articles written at the venues by their staff – experienced journalists who prepare event previews and reviews, athletes' press conference highlights and flash quotes of winners or in the event of major surprises.

Meteorological services store information about the current weather situation and forecasts in the Central Repository servers. Transportation services also store updates in transportation schedules.

Accreditation and Sports Entries system stores data about all athletes and officials in the Central Repository servers. This data is used by the Results System together with data about other participants and organizers by a number of different applications supporting Games logistics.

Information Diffusion and retrieval Systems make information stored in the Central Repository available in two different ways.

For some pieces of information, dissemination is defined well in advance, such as for printed results reports, or results data feed to News Press Agencies. For each report the locations at which they have to be printed, or which agencies will have to receive them is defined before the Games. Once the OVR system uploads a report or message to the Central Repository, appropriate software will trigger its distribution to predetermined addresses.

In a similar way this information diffusion software broadcasts results and other data to the systems that host the official Games web site, and systems of other Internet providers who have subscribed to this service, known as "Internet Data Feed" (IDF).

Information stored in the Central Repository is also available on request. Results, background information and news can be retrieved from any of the thousands of PCs installed at all venues, media centres, Olympic villages and other accommodation sites. The application allowing this information retrieval is usually called the "INFO" system. In Athens 2004 and Torino 2006 results were also available on request from dedicated mobile phones, and for Beijing 2008 onwards distribution via mobile telecommunications will become a regular service.

An extremely important information retrieval system that is also centrally supported is the remote CIS which allows Radio and TV Commentators to have the same level of services at remote locations as those who are commenting events live from the venues. Thanks to this system, a lot of commentaries are made from the central International Broadcasting Center where most of broadcasters have their own studios. In the near future this CIS service will be available remotely at any location worldwide.

3.2.1 INFO – Intranet system of the Games

At any Olympic Games, it is not only the athletes who are under pressure but thousands of journalists are also working in tight schedules, and they need access to many different kinds of information. A journalist watching Rowing may need to know who won a Handball match on the other side of the city because he has to report for that event as well. He would also like to know what the team coach said at the Press Conference after a Basketball match. Athletes in the Olympic Village would like to learn the outcome of the draw held minutes ago at the venue. A competition manager would like to know how many athletes finally arrived at the host city in order to plan their training schedule. A TV Commentator needs some historical statistics in order to prepare for an upcoming event.

Answers to all of these questions will come from the INFO system, a highly visible, all-purpose intranet-based tool that acts as an information hub for the 200,000 accredited Games participants. This system must be designed for a very special set of customers: thousands of first-time users who need to move around the Olympic venues and use INFO.

The system has to be understood at first glance and with minimal training, and everything needs to be self-explanatory. Navigation through the different data bases should lead users quickly to the data that they need – results, sports history, athletes' biographies, news, medals, transport schedules or weather reports – in one of several languages (English and French, plus at least the local language).

The INFO system is an extremely important tool for journalists reporting from the Olympic Games, particularly, since reporting from the Games is quite different to reporting from single sport events. The International Olympic Committee limits the number of journalists from each country that can be accredited at the Games, because the number of journalists who would like to attend is far too high. As a consequence, most journalists must report on a number of sports (according to some statistics on 7–8 sports in average), and on some sports on

which they have never reported before. Also very often, events in these sports overlap, and journalists must choose which event to attend. Because of this most reports are based on information retrieved from the INFO system, where the reporters are able to find not only the result, but also two other key elements for each report – the athletes' biographies or teams' profiles, and flash quotes (interviews) or press conference highlights with winners and major surprises.

According to the very precise INFO system statistics from the last summer Olympic Games in Athens 2004, the average number of INFO page views was about 400,000 a day during the 34 days of operations, with a peak of 920,000 views. There were a total 16,000,000 page views, and out of that 31% were related to results, 24% to athletes' biographies, 27% to the games schedule, 10% to news (mainly flash quotes and press conference highlights) and 8% to all other information [2].

At the end of the Athens 2004 Games there were tens of thousands of pieces of information stored in the INFO section of the Central Repositories – more than 11,000 athletes' biographies, more then 12,000 result reports, more then 6,000 news items, etc [2].

3.2.2 Commentator Information System (CIS)

With around 4 billion people watching the Olympic Games on television, getting results to broadcasters across the world is vital. CIS is a browser-based application that displays results on touch-screen PCs at the venue broadcast sites in a fraction of a second, so that they can be instantaneously dispatched across the globe.

By touching an intuitive screen icon on a touch-screen display, radio and TV commentators and producers have instant access to information in their choice of official languages. The wealth of information stored on the system includes live scores and results, together with different up to the second statistics and analysis enabling commentators to provide their audience with accurate and real time information.

CIS provides information on progress throughout the event, details of times and/or scores in the event and how individual athletes or teams stand in comparison to other competitors at that time. It also gives information on the weather conditions affecting the competition, medal standings, flash quotes, etc.

In Athens 2004 there were 1,500 CIS terminals installed at the venues and the International Broadcast Centre. The application supported more then 300 sport specific screens. OVR systems sent 477,000 messages to the CIS system during the 16 days of competition, with a peak of 47,000 a day.

3.2.3 Information retrieval from the mobile telecommunications

The first regular information retrieval service from dedicated mobile phones was available in Athens 2004. Much better and improved services were provided during the WOG in Torino 2006. There were more then 2,000 subscribers to the so called Wireless Olympic Works (WOW) system who were able to access a subset of the INFO data base, and to receive SMS messages with results of pre-selected events. Performances were reasonable, but only when the file size of data to be downloaded was not too large. According to the Beijing 2008 Olympic Games

organizers, a similar system, but with improved functionality and performances will be available, primarily for the media reporting from Games.

3.2.4 Internet Data Feed (IDF)

Since the first official Olympic web site was introduced at the Atlanta 1996 Olympic Games, diffusion of results and other information through the Internet has become more and more important. From 300 million hits and 10 million users in Atlanta 1996 [1], the number of hits rose to several billions and the number of users to hundreds of millions in 2004 and 2006 [2]. Furthermore, Olympic results and news are not only available at the official Games web site, but also from a number of other media organizations, International Sport Federations and National Olympic Committees who also provide this information on their own web sites.

In order to allow quick and reliable update of web sites, the Games Information Diffusion System broadcasts the IDF to the servers of all Internet providers who have subscribed to this service.

The IDF is designed in such a way that data sent from the Results System to the Central Repositories and to the central CIS application, together with selected INFO data base updates, is transformed into XTML pages or downloadable PDFs, and then broadcast. All users receive the same feed, and select the data that they need.

3.2.5 World News Press Agencies Results Feed (WNPA Results Feed)

Major World News Press Agencies – Agence France Press, Associated Press, DPA, EFE, Kyodo, PA, Reuters, SID and others, are some of the most demanding and sensitive users of Games information. They were the first users who insisted on the direct results data feed. Each of them provides news service to thousands of clients worldwide – mainly different media organizations – and all of them require information as soon as possible. Since the 1976 Montreal Olympic Games, the Organizing Committees' (OCs) computer systems provide these results electronically, through the WNPA Results Feed.

Today the systems providing this feed are specially designed in order to be as reliable as possible, and are isolated from all other systems and their potential malfunctioning. Software routes and tracks the delivery of messages, and allows the re-sending of messages on request.

The content of messages, their structure, and timing of delivery are defined by the International Olympic Committee WNPA Working Group, in which all major agencies are represented by their editors and technical experts. All agencies are interested that these feed specifications are as stable as possible and that they do not change from Games to Games, to remain compatible with the agencies' receiving software.

During the Athens 2004 Olympic Games, press agencies received 25,000 WNPA messages with a peak of 2,200 per day [2].

3.2.6 Printed results distribution

Although it is clear that an increasing number of users are computer literate enough to easily retrieve information from INFO, CIS or the Internet and that the

modern video-boards installed at the venues provide a lot of information – still a lot of users require or just prefer printed reports.

Competition officials require printed Start Lists in order to be able to check that all athletes are at the start, in the correct lane or track, etc. Journalists and TV Commentators like to manually record results on the Start Lists, and to make notes on the paper report which they use either while commenting on the event or while writing their reports.

It is true that the number of printed and copied reports is reduced from Games to Games. In Atlanta the organizer produced and distributed approximately 90 million copies of printed reports, and in Athens this number was reduced to some 55 million. It remains a challenge for all future organizers to reduce this number significantly.

During the Athens 2004 Games the Venue Results Systems produced 11.270 different printed reports, PDFs of which were sent to the Central Repository. The peak was 979 on one day [2]. Once received at the Central Repositories servers, PRD (Print Distribution) software distributed them to those locations and printers which were defined for each output before the Games in the appropriate distribution tables. There were approximately 300 dedicated printers installed for Results reports. PRD software, like other diffusion systems, route and track outputs delivery, and on request will re-send missed reports.

4 Games management applications

Computer systems supporting behind the scenes logistics ranging from accreditation and accommodation to staffing and transportation are not as exposed as the functions described above. However, this does not imply that those application areas are less important to the Games organizers, because it would be practically impossible to prepare and host the Olympic Games of today's magnitude without these systems.

4.1 Registration and accreditation systems

All Olympic Games participants (approximately 200,000 persons at the Summer Olympic Games and approximately 100,000 at the Winter Games) are registered in the computer system data bases. Half of these are the so called "Olympic Family" that consists of teams (athletes, trainers, coaches, medical and technical support teams), officials who manage and officiate competitions, media (written press and agencies journalists, photographers, TV producers, commentators and technicians), protocol and marketing guests. The other half are Games organizers including paid staff, volunteers helping them in a number of areas, providers of different services, etc.

The scope of data stored in the systems varies depending on each participant's function and the requirements of other computer applications supporting the Games logistics. For teams and media, data is provided by their National

Olympic Committees. Data on other members of the Olympic Family are provided by their respective organizations or the IOC. Information about organizers is mostly received from other computer applications – like staffing, volunteer registration and selection, etc. Because of the security background checks now required by law enforcements agencies, the deadline for provision of these data is usually half a year before the Games.

Once data are entered in the system they are used by number of other computer applications, allowing people in charge of different functions, such as organization of arrival/departure, transportation and accommodation, to plan their services in details.

A few weeks before the Games accreditation documents – photo ID badges which ensure that only eligible participants can attend and participate in the Games – are issued. These ID badges have either a bar code or a chip that allows people and/or scanning equipment to check if a person is authorized to access any particular area within the Olympic venues and sites.

For people coming from other countries ID badges are sent to their National Olympic Committees or the organizations who registered them, since an Olympic Games accreditation is equivalent to granting a visa for the duration of the Games. Once the participant arrives in the host city, after a check of his/her identity, the ID Badge is validated and activated and can be used, also for free access to public transportation.

Without adequate computer system support it would be very difficult to organize the process of producing some 200,000 ID Badges, their distribution and validation in such a short time, particularly during the peak few days before the start of the Games when more then 15,000 ID badges must be issued and/or validated during a single day. A network of hundreds of PCs is installed in the Accreditation centres, and a number of them are connected to the special equipment that produces the ID Badges.

4.2 Sport entries and qualification system

This system collects and manages the official entries of qualified and eligible athletes and teams to the Olympic Games.

The overall objectives are:

- ensuring that only eligible athletes are formally 'entered' to participate at the Games
- ensuring that each individual is qualified in accordance with the rules of International Sport Federations
- ensuring that all athletes are confirmed by their respective National Olympic Committees to represent their nation

For most athletes, qualifying for the Olympic Games is their best achievement, and accurately representing the official qualifying achievements is critical to fair competition.

This system maintains the criteria for qualifying individual competitors, pairs, relays or teams based on the minimum and maximum qualification standards for any event, types of qualification and quotas, combining around 1,000 different criteria across all the sports. It is usually activated 2 years before the Games. Before the Athens 2004 Olympic Games more then 16,000 athletes were registered in this system, and by the end 10,500 of them have participated at the Games in 301 events in 37 sport disciplines [2].

Information about athletes used during the Games by the Results and INFO systems is a combination of data from this system and from the accreditation system.

4.3 Protocol System

The Protocol System assists organizers in the coordination, scheduling and provision of appropriate services for a few thousand VIPs, including their registration, organization of VIP events and other VIP arrangements.

4.4 Arrival and departure system

This system gathers expected arrivals and departures data for the Olympic Family and provides the information to the groups responsible for managing the travel arrangements as well as the welcome greetings for the delegations.

4.5 Accommodation system

Planning accommodation for tens of thousands of Games participants, allocation of rooms at Olympic Villages and hotels is supported by this system, which has most of the functionality of a typical Hotel Reservation System.

4.6 Transportation system

The transportation system computerized support provides for the programming, planning and scheduling of transport services and fleet management for the Olympic Family. The system allocates the available transportation resources according to the service levels established for each athlete and group. At least it must schedule and dispatch a fleet consisting of 2,000–3,000 buses/minivans and 3,000–4,000 personal vehicles in order to transport 40,000–50,000 persons from their accommodation sites to the competition and training venues, media centres and other Games locations [2]. The Games schedule is different every day, and a number of people will make decisions as to where they must/wish to go on the next day very late in the evening because this may depend on draws or results of the previous day, etc. In such an environment proper dispatching of the fleet is essential, and would be practically impossible without appropriate computer systems support.

4.7 Medical encounters system

This system gathers information relative to the different levels of healthcare, generates reports for the medical management organizations (IOC Medical Commission, Department of Health and others) and provides an on-line summary of each case history.

4.8 Volunteers registration, selection and assignment

Volunteers are non-paid members of the OC staff. Regardless of the size of a host city and of the OC budget, it would be very difficult to recruit and hire the required number of people who have the necessary skills (languages, computer literacy, etc.) for the limited period of time (20–30 days). For the Summer Olympic Games the number of people required for the tasks of computer operators, translators, teams and VIP hostesses, drivers, access controllers, etc. exceeds 50 thousand. For this reason all Games organizers are forced to attract local people to volunteer for these positions, and often to use their holidays or vacation for this purpose. After a campaign to attract people to apply for these jobs, it is necessary to register all candidates, and organize their training and selection. In Sydney and Athens there were more than 200,000 candidates, and in Beijing they expect many more. An application that supports this area helps organizers to select and assign people with the required skills to the best positions, considering several parameters, such as home address (in order to minimize needs for transportation), special skills, etc.

4.9 Uniforms planning and distribution

This application is responsible for the planning, ordering and distribution of uniforms and accessories for the Games workforce (paid staff and volunteers), competition officials, etc. There are typically 15–20 different types and/or colors of uniforms depending on the functional area and/or status of a person. The total number of uniforms to be provided at the summer Olympic Games is about 70,000–80,000 [2].

5 Requirements definitions

As in all other computer applications, a thorough understanding of user requirements is the key to success. What (and when) results information is required by athletes, coaches, officials and competition management? What result information needs to be displayed on a scoreboard or in the TV picture that will allow even those people who are watching this type of competition for the first time in their life to understand it? What level of detail is needed in printed reports? What information should be distributed to a written press journalist and when? What should be available in the INFO system and on the Internet and when?

Content and presentation of results information is mostly based on tradition, and event organizers usually rely on the companies providing the IT services to define these. Today, when a number of users expect to receive information electronically, problems caused by lack of standards have become more serious, as users of data feeds have to reprogram their 'receiving' software every time a different format is used.

Unfortunately very few International Sport Federations or other user groups have any documented requirements for these results services, or any standards. Some of the few professionally developed and maintained documents and standards are those that have been developed by the International Olympic Committee.

In order to ensure smooth operations of the Olympic Games Information Technology and to properly manage user expectations, in 1994 the IOC launched the Olympic Results and Information Services (ORIS) project with the objective of identifying and documenting the user requirements.

Key deliverables of the project are the ORIS documents that provide a precise definition of all outputs (printed reports, scoreboards, Information retrieval system, etc.) together with information about 'who', 'when', 'where' and 'how' these are required. Documents also include procedures defining who is responsible for preparation, collation and processing of data, when this must be done, who must check and approve outputs before public release, etc.

ORIS documents were developed for all 38 summer and 15 winter sports/disciplines that are on the program of the Olympic Games. For each sport, an ORIS Working Group was established. The IOC invited representatives of the International Federations, experienced journalists and media researchers to provide input. They worked together with the ORIS Project team that is made up of IT experts who are experienced in the development and implementation of Olympic IT Systems.

Thanks to the contribution of more than 210 sport officials, 180 media experts and 110 IT specialists coming from more than 40 countries, the first version of ORIS was developed between 1994 and 1999 and was used at the Nagano 1998 winter, and Sydney 2000 summer Olympic Games.

The ORIS Project team continues to update documents, due to the permanent development of sports (new events, improved formats and rules), changes in user's expectations due to increased computer literacy, and developments in information technology itself. Updated versions were produced for Salt Lake City 2002, Athens 2004, Torino 2006, Beijing 2008, and update process for Vancouver 2010 is almost completed.

A number of International Sport Federations have begun to use the same ORIS documents for definition of the IT requirements for their World Championships and other events.

6 Systems architecture

There are two key factors that have major impact on the Olympic Games computer systems architecture: the first one is that systems providing results and information diffusion must be fault-free, and the second one is maximum security.

The most critical services are isolated in a separate computer network which must provide both a high level of availability and of data integrity. It is completely independent from the outside environment, and does not share any resource with any other system or service, including the telecommunication network.

All the other non mission critical applications, such as OC internal e-mail, payroll, document management, etc. are grouped on another network in which services are of a lower standard.

Designers of the computer network supporting vital functions take considerable care about several aspects which are collectively known as 'Business Continuity':

a) redundancy of equipment, network infrastructures, systems and applications assuring that there are no single points of failure, and allowing fail-over to redundant architectural elements upon failure of a primary element;
b) back-up and restore functionality allowing quick restart of processing from some point in time when systems stored the content of data bases, and using the log of all transactions after that;
c) disaster and recovery solutions: partial or complete networks can be restarted from another location in the case of complete failure or catastrophic disaster of the primary systems.

OVR systems are designed in such a way that they could work alone without being connected to the Games network. They should at any moment satisfy all basic requirements of the users at the venue. All hardware components of these systems are duplicated or triplicated, fail-over switches between them are automated as much as possible, but should still be able to be manually operated when required. All input data coming from timing and scoring devices is stored in parallel in at least two different servers. Two fully separated configurations are attached to different power supplies, etc.

For support of the Central Repositories and Information Diffusion System there are two main data centres installed. The primary data centre hosts all servers and the central data communication equipment for normal operations, and the secondary one acts as a back-up data centre in case of emergencies.

All file servers use clusters for redundancy. Applications and processes are assigned to either node in the cluster thereby distributing the workload during normal operation. Processes fail-over to the other clustered node upon failure.

Monitoring of all systems is organized at a neutral location usually called the Technology Operations Centre (TOC), from where experts using different data base and network monitoring tools control operations, manage configuration and distribute software.

It is also equally important that all system components and all interfaces are based on stable and proven technologies. The Olympic Games operations are so risky that there is no room for testing of prototypes or '0' versions of any hardware or software component. Some previous organizers have paid a very high price for attempting to implement completely new and unproven solutions.

7 Security

In addition to running fault-free systems, the other key challenge faced by Games organizers is system security. A system open to the world could potentially be a huge security risk. It is necessary to prevent any attacks from viruses or hackers during the Olympic Games either from inside or outside the Games network. During the 16 days of competition in Athens, more than five million IT security alerts were recorded, of which just 425 were serious and 20 critical [2]. Intrusions included accredited people attempting to disconnect INFO work stations in order to connect personal laptops to access the Internet.

The first step is complete isolation of the Games network from the outside world, particularly the Internet. After that it is necessary to prevent unauthorized access within the network. At all work stations located in public areas, all inputs except the keyboard are physically disconnected to prevent anyone from being able to insert or attach his/her equipment (diskettes, CD-ROM, memory sticks, modem, etc.). Additionally, the screens and keyboards on the work stations in public areas will remain blocked until the application takes over and privilege password and special codes are added so that at the least attempt to re-configure a machine will be automatically reloaded. All servers and workstations are equipped with the full range of security systems such as anti-virus software, firewalls and Intrusion Detection System (IDS).

All interfaces with systems for broadcasters, new press agencies and Internet providers are designed in such a way that all traffic is strictly monitored and controlled. The IDS is heavily used to monitor known patterns with the addition of custom made rules to monitor anomalous network traffic that does not match the well known traffic pattern.

The location of the main and back-up computer centres is top secret, and very few people know where they are.

8 Software and testing

Software for the Games computer systems is a combination of the standard operating systems, data base/data communications, browser and monitoring packages, combined with propriety software solutions developed by companies that are partners of the IOC and OCs.

Propriety software alone consists of millions of lines of code, and more then 250 developers work on its development.

Software development usually starts 3–5 years before the Games, as most of the systems must support the Games Management Systems during the planning phase, and be ready to be implemented at Test Events that are organized a year before the Games.

Until Barcelona 1992 and Lillehammer 1994, integration of all solutions was managed by a team of the OC's experts, but since computer systems have become so huge and complex solutions, this task was subcontracted to a large company

specialized in systems integration (IBM 1996-2000, Atos Origin from 2002). The same company is in charge of development and implementation of Information Diffusion and Games Management Systems, and a long-term IOC partner for Timing & Scoring and OVR system is Swiss Timing. The IOC has signed long-term contracts with these companies, in order to benefit from their experience, and to allow smooth transfer of solutions that can be reused.

The most complex tasks in Games software preparation are testing and rehearsals. All those people who have worked on the IT projects for the Games know very well that the key to successful operations is simply testing, testing and testing, followed by rehearsals.

After the development teams of different companies have completed the code and performed 'unit' tests, software is installed in the special 'Integration Testing Laboratory' usually located in the host city of the Games.

In the Integration Lab typical hardware configurations are installed, allowing the testing of solutions for each sport and function. For that purposed in the Athens 2004 Games Integration Lab more then 400 workstations and more then 40 servers were installed [2].

Specialized teams integrate programs into Games configuration and test integrated modules using hundreds of previously prepared scenarios.

Once this phase is completed, a set of volume and stress tests begun that should ensure that the expected performance of the complete system will be achieved.

The last step in testing are the so called 'Homologation tests', where representatives of International Sport Federations and media, together with the IOC delegated experts (ORIS Team) check that the systems deliver the functionality specified in the ORIS requirements documents, and that the systems are capable of handling all exceptional situations that can be anticipated.

Two to three months before the Games are due to begin Games operations are rehearsed. At least, two 3–4 days of rehearsals are organized. During them the complete IT team simulates operations during the most critical days of the Games. In addition to the regular situations, testing scenarios includes a lot of incidents and mishaps that might occur during the Games, ranging from power outages to the cancellation of events and their re-scheduling.

9 Hardware

The hardware platform that will satisfy the architecture and security requirements is usually provided by sponsors and/or partners of the IOC and OCs of each Games. Because the network of systems has such a complex architecture which must support many different applications, it is not possible to use hardware from just one manufacturer, as was the case 10 years ago. Today sponsors and partners are usually supplying equipment that is installed in the public areas (PCs, Printers), while all behind the scenes hardware is purchased or rented from specialized companies.

The quantities of equipment used at the Games are extremely impressive. Following are data about the computer equipment used at the last two Olympic Games [2]:

	Athens 2004 (Summer Games)	Torino 2006 (Winter Games)
Servers	900	385
Work stations	10,500	4,700
For results systems	4,000	1,800
For INFO retrieval system	2,500	800
For Commentator Information System	1,800	950
Printers	4,000	700
Routers	300	140
Switches	2,000	800

10 Installation

Installing the above mentioned quantities of equipment during a period of 5–6 weeks is a real challenge. Installation planning starts a few years before the Games, when it is necessary to identify the space required and locations of equipment at venues that will be built or renovated. At this stage very few people have a clear idea of how the computer system will be designed, of how much equipment will be required at each location or of how they will be connected. Planning is usually based on experiences of previous Games organizers.

Once the final computer systems configuration is defined, which usually happens 2 years before the Games, detailed planning of installation and related logistics begins.

At the summer Olympic Games computers are installed at more than 60 locations. Some of these are newly built venues (and construction is usually late) and installations planning must include considerable amounts of contingency time. At a number of other locations – e.g. hotels, airports and convention centres – installation can not be begun too far in advance, as these facilities must continue to function normally before the Games.

Once installation starts, approximately 500–600 'boxes' (servers, PCs, printers, routers, etc.) have to be installed per day. If just one venue or site is not ready, these numbers of pieces of equipment to be installed on the following days is increased. Work by the technicians from the different hardware suppliers must be perfectly coordinated, because in most cases installation of different equipment can not be done in parallel, but in some technologically determined sequence.

Since the Atlanta 1996 Olympic Games, when the quantities of PCs to be installed entered the thousands, Games technology suppliers began to organize a so called 'PC Factory'. This is the facility dedicated for storage, assembly and

configuration of workstations and servers. In the first step, devices are configured according to their function and final location. After that, through a central server, the necessary operating system is transferred to the computers in a consistent and reliable manner. After the equipment is properly configured and verified, it is packaged and shipped to the venues. This process enhances the information network's stability because it loads each computer with an identical version of the appropriate operating system. In Athens 2004 the PC Factory was a 5,500 square metre storage area and a 500 square metre configuration facility, with the capacity to configure and ship 500 units a day [2].

11 Future challenges

By accurately analyzing user's requirements, future organizers can learn a lot about the design and implementation of computer systems at future Olympic Games.

- Sport officials expect that computer and other technologies will further improve the accuracy and precision of results measuring, and will develop new tools that will assure fair and impartial judgment of athletes' achievements.
- Games organizers would like computer applications that support the Games logistics to be fully integrated and more automated.
- Media, particularly written press journalists, would like to connect their own laptops to the Games systems in order to retrieve and download information that they require to prepare their reports – results, news, biographies, etc. Connection should be wireless allowing them to work at any location of the venues and other sites.
- Newspapers and other media organizations would like to have access to the INFO content from their offices worldwide.
- TV Broadcasters would like to have the CIS services available remotely, in their countries.
- A lot of media users would like to have real time access to the video footage of events, allowing them to replay actions which they have missed, or that they would like to analyze again.
- TV audiences are no longer satisfied with the concept of 'one broadcast fits all', and people would like to choose which event they actually want to see at a particular moment.

Most of these demands are already affordable from a technology point of view or will be available in the near future. The expected convergence of different technologies (Internet, TV Broadcasting and Telecommunications) will allow most of these requirements to be met.

The massive distribution of audiovisual content has gone hand-in-hand with the so called digital convergence. Thanks to the large band-width (ADSL or cable) and the improved quality and efficiency of some compression codes,

on-line distribution of audiovisual content is now a reality. At the same time, the mobility and interoperability of various networks and devices can lead to new forms of interaction.

Having a technology solution does not mean that it will be implemented. There are lots of other barriers and obstacles preventing Olympic Games organizers from using some of these new developments in technology.

The first group of reasons is a complex mixture of budget, marketing and legal constraints. For some of the new technologies it is difficult to justify their temporary installation, or the investments in required infrastructure are too high without any end-user after the Games. Sometimes a loyal long-term sponsor is not capable of providing the state-of-the-art solution. The physical and legal content protection mechanisms which tie content to a particular source or platform are a huge barrier to the possible benefits of convergence of Internet and Broadcasting technologies.

The second reason is the fact that people need some time to become familiar with new technologies and solutions. Is the period of 16 days of the Olympic Games long enough for such a heterogeneous group of people as the Olympic Family to learn how to use these new tools?

However, we certainly expect that a further increase in computer literacy of users together with new developments in the computer and telecommunication industries will allow future Olympic Games organizers to improve the level of computer services. We hope that the use of computers will contribute to more accurate and fair judging of the athletes' performance, and that information from the Games will reach all parts of the globe in the most efficient way possible.

References

[1] Media kit, "IBM at the Olympic Games" distributed at the Sydney 2000 Olympic Games.
[2] Atos Origin Olympic Media kits distributed at the Athens 2004 Games and Torino 2006 Winter Olympic Games.
[3] Swiss Timing (SWATCH, OMEGA), Press kits distributed at the Sydney 2000 and Athens 2004 Olympic Games.