Multimedia systems and real-time systems : some analogies and similarities

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ABSTRACT

Real Time systems and MultiMedia systems have been developped separately for a long time. The vocabularies are different, but some concepts are similar and it seems now useful to analyse and compare these systems in order to define more generic or common solutions and understanding. The applications characteristics, the operating systems mechanisms and the modeling techniques are analysed for both of these systems.

Keywords: Multimedia systems, Real-time systems, real-time constraints, QoS parameters, QoS management, performance, scheduling.

1. INTRODUCTION

The major idea of this paper is to study both of the multimedia and the real time systems according to common criteria in order to define their similarities or analogies and their differences. As in all the computer applications, the term "system" may have here two acceptions, the operating system itself strictly speaking, or the complete architecture including the application and all the support means (hardware and operating system, networks and protocols stacks). We are interested here by both of these acceptions.

The paper is structured as follows. The section 2 presents a general description of multimedia and real-time applications. The section 3 describes the functional aspects of MM and RT applications and it describes different requirements in terms of QoS and time constraints. The section 4 presents the operating systems point of view in terms of communication models, QoS management and scheduling techniques in MM and RT systems. The section 5 gives a brief analysis of some paradigms present in MM and RT systems. The section 6 presents the modelling point of view before to conclude in section 7.

2. GENERAL CHARACTERISTICS

2.1 Multimedia Systems

Multimedia can be defined (in a basic form) as a computer processing of text, of still and moving images, of video and sound. In general (and in a distributed applications context), the term multimedia implies different aspects:

- integration of different data types (audio, video, text, graphics) provided from different sources within computer applications,
- interactivity between different application processes within a single environment,
- different transmission types and real-time constraints associated to the continuous media.

Multimedia means an integration of continuous media (e.g., audio and video) and discrete media (e.g., text, graphics, images) through which information can be conveyed to the user in an appropriate way. Continuous media are characterised by time dependent sequence of information units, that involve requirements as synchronisation and real-time transmission. Discrete media are more often time independent information.

MM applications can be grouped into two general categories: general public and professional applications [24].

The general public applications are addressed to a great number of persons. The multimedia information has been incorporated in applications such as: electronic consultation and catalogues, telemarketing, entertainment, and others consumer services. These applications require still more storage, broadcasting, database and retrieval information techniques.

Professional applications have been developed in scientific, technical, arts, education and industry areas. These applications require still more consideration in communication, in dependability, interactivity and QoS aspects.

In the other hand, MM applications can be grouped in: conversational and presentational applications (also called people-to-people and people-to-system applications [15]).

Conversational applications (people-to-people) provide a communication support between people (between two people, or groups of people) to back interactive activities such as co-operative work. Conversational applications are characterised by the request of real-time communication to maintain their interactive character.

Presentational applications (people-to-system) provide a communication support to a person or a group of people that communicate with a distant system to reach, find or interact with multimedia information. In this case, the interactive character of applications is not so noted and real-time communication is not required.

2.2 Real-time Systems

Real Time systems are systems which have to react to an environment and which have to meet its constraints for dependability, for safety of people, for security, for the quality of products...

The RT systems are born for military purpose and have been developped in industry, in continuous processes and in manufacturing applications. They have been introduced in transport (avionics, trains and cars) and they are now present more and more in our life (in games, in telecommunication applications, in building automation applications, in medicine).

Real Time systems are characterized by the fact that an execution of a task is generally triggered by an event, (a change of state or a time tick) and that the result must be obtained in a given delay. This is a very simplified definition. To have more details see for example [22], [34], [21]. These systems are also called reactive systems [3], [18]. Some authors speak abour soft RT and hard RT according to the criticity of a fault regarding the satisfaction of RT constraints.
In a first approach, considering RT and MM systems, they have both to manage real time data issued from sensors (including microphones, video camera, speed sensor, and all physical information). In a MM system, time constraints have to be met, between images and sound for example, a MM system is then a real time one. In RT systems, the supervision function and the man machine interfaces include more and more MM sub-systems.
Therefore this paper tries to establish some parallel, some analogies, and to identify the differences or complementarities between MM and RT systems.

3. APPLICATION POINTS OF VIEW

From the application point of view, the main criterion to be used to compare MM and RT systems is the specification of the needs.
An application is composed of functions described or specified with the following attributes:

- Starting criterion, (operator, condition, event, call by another function, ...)
- Result of the function, (messages, actions, ...)
- Function performances (maximum delay of the function run-time, constraints, ...)
- Function decomposition in more elementary functions
- Exchanges with other functions

Such aspecification is composed of two types of elements, some are purely functional, other are more quantitative.

3.1 Functional aspects

3.1.1 Exchanges between functions

The exchanges between functions are of two types, exchanges of data and exchanges of events associated to the well-known data and control flows. An application combined usually both of them as well in MM as in RT systems. These exchanges are supported by an application protocol. Two types of protocols are mainly used, each of them being based on one of the types of co-operation: the client-server model and the producer-consumer or publisher-subscriber one [37] [38].

Client-server model

The client-server model establishes a co-operation link between two processes. The client is the requester of a service provided by the server. The services depend on the application protocol, some define only "read" and "write" operations, other provide various services according to the managed objects, ("Play" a music record, "Start" a task, "Request" a semaphore,...). The server executes the service and sends the response to the client.

Producer-Consumer model

The producer-consumer model is also a peer to peer model. It main characteristic is: the transmission of the information is triggered by its producer, without being requested by another partner. Two examples are: "Event-Notification" of a change of state, "Information-Report" of a periodic piece of information.

3.1.2 Number of participants

Both of the previous models are peer-to-peer. RT and MM systems need obviously other co-operation models.
Indeed with the development of smart instrumentation devices, RT several distributed processes have to co-operate, as well by exchange of data as by synchronization mechanisms or control exchanges.
These peer-to-peer models have to be extended to multipeer models, when a constraint is expressed on several processes which are clients, servers, producers, consumers. Therefore several models are studied: multiclient-server, client-multiserver, multiproducers-consumer, multiconsumers-producer [10], [1] [2].
The same remark may also be made considering MM systems (See **§**).

3.2 Quality of service and performances requirements

In RT systems as in MM systems, the Quality of Service depends on the applications.
In RT systems the QoS is required through the expression of constraints on the data or on the tasks and it will be shown in **§ 3.2.2** how these constraints may be expressed on events.
In MM systems the term QoS defines the set of quantitative and qualitative characteristics of a multimedia system necessary to achieve the required functionality of an application [43]. Thus, different levels to treat QoS of MM systems can be identified: user/application level, system level and device level [36] [29] [43] [45].
In MM systems, the performance requirements refer usually at network and communication sub-system functionalities. Multimedia applications have the specific features [15]:

- they may require real-time transmission of continuous media information (as audio and video)
- volumes of data to be exchanged are substantial
- many application are distribution oriented

In MM some quality of service has not to be required. The flows characteristics are known and some constraints are implicitely given. In MM it is then not necessary to explicit all the time constraints. The intra-media relationships existing in a flow of images, and an audio stream are implicit constraints related to the continuous media.

Based on these features several performances criteria can be expressed quantitatively and applied to the communication networks, that enable define QoS parameters for multimedia transport protocols: throughput, transit delay, delay variation, error rate, multicast and broadcast capabilities, and others as priority, security, burstiness, jitter, and acceptable bit error rate. [36] classes these different parameters as static and dynamic. Parameters that are fixed or static are: throughput and error rate for a given quality. However, if an user may accept a degradation of the quality, error rate could be higher and acceptable in this case. Dynamic parameters are: delay, delay jitter, security, and priority. They are highly application dependent.
These characteristics of MM QoS may be also found in TR QoS.

3.2.1 Constraints

The constraints in MM systems can be very different and they depend on:
the environment where multimedia applications are running (architectural support, number of participants, distributed or no, etc.),

the nature of the application (presentational, conversational, retrieval, co-operative, etc)

the media that it manipulates and their integration level in the application (discrete and continuous media).

MM system requires real-time performance in handling a number of media types. This is especially true for the continuous media types such as audio and video [46]. Digital audio and video services are characterised by a continual delivery of segments over a finite period of time from the beginning of the audio or video sequence. Each segment of this sequence is strongly time related to the previous segment. To preserve continuity in playout at a receiver, successive segments have to be delivered within tight timing constraints otherwise the service becomes disrupted [17].

Another important characteristic in multimedia applications is that the multimedia presentations are often interactive. Thus, multimedia constraints should be capable of interactively changing the status of the constraints and the constraint network. A consequence of the interactive nature of multimedia applications is that the constraint system must be dynamic; i.e. constraints can be added, deleted, activated and deactivated at runtime [19].

The temporal characteristic in multimedia systems is strongly-related with the response time request by multimedia system (lifetime of messages) to conserve the interactive character on multimedia applications. Thus, temporal constraints are depending of application type (conversational applications that request real-time communication, and presentational applications that not request it). The temporal constraints are translated into QoS parameters (such as transfer delay, end-to-end delay, etc.) at communication level.

It is possible to define two types of constraints in multimedia applications:

- temporal constraints: that is related with the transport time and end-to-end delay (i.e. quantified time). This constraint in distributed multimedia systems is catalogued to be a ìsoft-constraintî, in contrast with the ìhard-constraintsî that are presented in Hard RT systems.
- synchronisation constraints: that is related with the maintenance of timing relationships between information units in a media stream and the maintenance of timing relationships among different media streams.

3.2.2 Time constraint expressions

This section present a classification of the time constraints usually encountered in RT systems.

In RT systems the time constraints are expressed on the data, on the tasks, on the events, in terms of lifetime, of deadlines, of earlier or later date of occurrence and so on. More generally, they may be classified into the following classes [40] [41]:

Absolute constraints

An absolute constraint is associated to an occurrence of an event. The date of a given occurrence noted $d(e_i)$ must occur in a given interval I determined by two bounds noted $l(I)$ and $r(I)$ (respectively left and right).

Definition:

If $l(I)$ and $r(I)$ are respectively $T_{\min}$ and $T_{\max}$

$e_i \wedge (T_{\min} \leq d(e_i) \leq T_{\max})$

***Particular cases*:**

Earliest date constraint

If $(r(I) = \infty)$, $e_i \wedge (T_{\min} \leq d(e_i))$

Latest date constraint

If $l(I)$=0, $e_i \wedge (d(e_i) \leq T_{\max})$

Instant constraint

If $l(I)$ and $r(I)$ are equal to T_p, $e_i \wedge (d(e_i) = T_p)$

Relative constraints

A relative constraint is related to the time between two occurrences of a given event.

Definition:

$e_i \Rightarrow \Diamond e_{i+1} \wedge \Delta T_{\min} \leq d(e_{i+1}) - d(e_i) \leq \Delta T_{\max}$

The same particular cases as in the previous section may be defined.

Particular cases:

Earliest date constraint with $\Delta T_{\max} = \infty$

$e_i \Rightarrow \Diamond e_{i+1} \wedge \Delta T_{\min} \leq d(e_{i+1}) - d(e_i)$

Latest date constraint with $\Delta T_{\min} = 0$

$e_i \Rightarrow \Diamond e_{i+1} \wedge d(e_{i+1}) - d(e_i) \leq \Delta T_{\max}$

Periodicity

$e_i \Rightarrow \Diamond e_{i+1} \wedge \Delta T_p = d(e_{i+1}) - d(e_i)$

Causality constraints

The previous constraints were specified only on occurrences of a same event. However, several constraints as response times, and coherence are related to several events. In this section, we analyse two types of constraints on related events.

We consider here the constraint between two events called "cause" and "effect". An occurrence of the event "cause" leads to an occurrence of the event "effect". Many examples may be given. In communication systems, a request must lead to an indication, and then to a response and finally to a confirm. In real time application an event cause as "tank-level>upper limit" has an event "effect" as "close a valve", "open another one".

Definition:

If **s** and **r** are respectively cause and effect, the constraints on the response time between an occurrence of s and the corresponding occurrence of r may be expressed as follows.

$s_i \Rightarrow \Diamond r_i \wedge (\Delta T_{\min} \leq d(r_i) - d(s_i) \leq \Delta T_{\max})$

Particular cases:

Earliest date with $\Delta T_{\max} = \infty$

$s_i \Rightarrow \Diamond r_i \wedge (\Delta T_{\min} \leq d(r_i) - d(s_i))$

Latest date with $\Delta T_{\min} = 0$

$s_i \Rightarrow \Diamond r_i \wedge (d(r_i) - d(s_i) \leq \Delta T_{\max})$

Instant

$s_i \Rightarrow \Diamond r_i \wedge (d(r_i) = d(s_i) + \Delta T_p)$

These previous constraints are expressed on the same occurrences of **s** and **r** (the occurrences noted **i**). Nevertheless, a less hard constraint could be expressed on not same order occurrences.

Temporal coherence or consistency

Several occurrences of events are coherent from temporal point of view when they occur in a given time window.

Let us consider n events e^l with $l \in [1,n]$.

$\forall k,l \in [1,n], |d(e_i^k) - d(e_i^l)| \leq \Delta T_{tc}$

We may deduce two kinds of constraint of this previous one [39]:

- a strict temporal coherence with the same occurrences of the various events
- a weak temporal coherence with occurrences of different orders.

In MM system these constraint expressions can be compared with the expression of synchronisation relationships: intra-media, inter-media and causal relationships.

3.2.3 Fault tolerance and dependability

In MM systems anomaly situations such as data delay and data loss, disruption to the presentation should be kept to a minimum [27].

In RT systems data loss, delays, and more generally the unsatisfaction of constraints must be detected and lead to switch the application in another running mode. In MM systems this running mode switching is equivalent with a QoS decreasing mode. But some faults are tolerated without effect on the application. For example, the loss of a data periodically transmitted is usually not an important error.

4. OPERATING SYSTEMS POINT OF VIEW

4.1 Communication management

In MM systems, communication requirements depend on the application type, and on the nature and relationships between media manipulated. Different applications define different co-operation configurations and require different communication supports. Real-time communication support is specially request in co-operative multimedia applications (and in all other applications where interactivity is an important characteristic to be guaranteed) when it is needed to transfer information with bounded delay time.

4.2 Communication models

In MM system, and in considering different criteria of classification, it possible to identify different configurations of multimedia applications. Three models are considered to classify the different applications [13]:

The first model is based on the number of partners and on the communication type [44]. The following configurations are included (client/server model):

- *UNICAST:* it represents a relationship between one sender and one receiver (1-to-1). Example: video/voice mail.
- *MULTICAST:* it represents a relationship between one sender and several receivers (1-to-N). Example: teleconferencing applications such as tele-lectures.
- *RETRIEVAL:* it represents a relationship between several senders and one receiver (M-to-1). Example: a user may get video and voice from two different database servers.
- *GROUP:* it represents the most general relationship between several partners. A group of senders what transmit data to a group of receivers (M-to-N). Example: teleconferencing.

The second model is based on data location relationships that exist between information sources [6] (producer/consumer model):

- *Simple local source*: In this model, data are located at a single source and transmitted to different destinations. This model presents the least synchronisation complexity (1-to-1 and 1-to-N). Example: a CD-ROM that contains sound, text and picture information
- *Single remote source:* In this model, a single data source is located on a remote location relative to the workstation managing the user/computer interface. In this case, the transfer delays of data transmission have to be considered (1-to-1 and 1-to-N). Example: access to distant databases.
- *Multiple local sources:* In this model, data are scattered across several devices. In this case, one needs to incorporate synchronisation mechanisms between different data streams (N-to-1 and N-to-M). Example: combination of voice annotation with images in an electronic slide-show.
- *Multiple distributed sources:* This is the most general model of data location. Information may be gathered from many sources on many workstations, and destinations may also be spread over several places. Different problems have to be dealt with in this case: locating and transfer delays across several connections and processing delays at one or more sites (M-to-N) Example: collection of audio and video data from distant databases.

The third model is based on information characteristics [44]: persistent or dynamic data.

- *Live:* In this case applications produce, transmit and play media units in real-time. Data are dynamic. Example: Teleconferencing applications
- *Synthetic:* In this case media units are retrieved from databases. Data are stored on persistent devices. Example: Tele-consulting applications

4.3 QoS Management

In MM systems, the management of QoS is realised in different phases:

- a first phase that enables the specification of QoS parameters and the level of services required by the application.
- a second phase that set up diver QoS mechanisms (QoS provision mechanisms, QoS Control mechanisms and QoS management mechanisms) to deal with the QoS specification.

QoS specification can be considered declarative in nature: users specify what is required rather than how this is to be achieved by underlying QoS mechanisms.

The QoS mechanisms are selected according to user supplied QoS specification, resource availability and resource management policy. QoS mechanisms (in considering the resource management) are considered as either: static or dynamic in nature [45]. Static resource management deals with flow establishment, resource reservation and end-to-end QoS re-negotiation phases (which is described as QoS provision mechanisms). Dynamic resource management deals with the media transfer phase (which is described as QoS control and management mechanisms) [7].

Two major strategies are considered [29] [28]:

- the reservation-oriented strategy assumes a full knowledge of the properties of the running multimedia applications and tries to reserve exactly the right amount of resources for that.
- the adaptation-oriented strategy. Adaptation of a multimedia application can be achieved by algorithms that can produce usable partial results and alternative implementations that take less resources than the previous implementation does. The adaptation strategy is used when the load of multimedia applications is not predictable. The application is allocated some resources and may obtain more available at run-time.

4.4 Constraints management

In MM systems, constraints management are realised through QoS provision, QoS control and QoS management mechanisms.

QoS provision mechanisms realise different functionalities : the translation between representations of QoS at different system levels (QoS mapping), the admission testing (comparison between resource requirements and the available resource in the system), and the resource reservation protocols (allocation of suitable end-system and network resources according the user QoS specification) [7] [45].

QoS control mechanisms deal with traffic control, time-constrained buffer management and communication protocol operations. These mechanisms provide real-time traffic control of flows based on request levels of QoS established during the QoS provision phase. Some functionalities of QoS control are: flow shaping, flow scheduling, flow policing, flow control and flow synchronisation [7].
QoS management mechanisms are required to maintain agreed levels of QoS (to adjust commit resources, to ensure that the contracted QoS is sustained). QoS management mechanisms include: monitoring, maintenance, degradation, signaling, and scalability mechanisms.

4.5 Scheduling

From the viewpoint of an operating-system designer, multimedia support is about handling time-dependent media. This time-dependency of continuous media suggests that operating system support for multimedia might well be provided by real-time systems [28]. MM systems must consider timing and logical dependencies, both internal and external, among different, related tasks processed at the same time. To respect the temporal constraints of the continuous media, the operating system must use real-time technical scheduling. But multimedia systems have different needs that traditional RT system [35]:

- A sequence of continuous media data results from periodic sampling from a signal of sound or video. From there, the processing of the units of data of such sequences, all the critical operations of time are periodic. The processing of the continuous media must be made in predetermined periodic intervals.
- In multimedia application it is possible to find tasks with both behaviours: periodic and random. For example, task such as pause, stop, resume are dynamic and are generated due to the user interaction (are a random behaviour) while that the control tasks (such as connection control, synchronisation control) have a periodic behaviour.
- The bandwidth required for the continuous media is not always rigorous. There are various algorithms of compression which use various ratios of compression for different QoS, and then the bandwidth required can be negotiated. If, there is not bandwidth requested for all QoS, the application can accept a reduction of QoS. A dynamic adjustment can be carried out according to the bandwidth available, by changing the parameters respective.
- For many applications, missing a deadline in a multimedia system is, though regrettable, not a severe failure: MM applications are characterised by soft real-time tasks. Soft tasks are characterised by soft deadlines, i.e. desired average response times, or by no deadlines at all. Soft real-time tasks usually require dynamic resource management, while hard real-time tasks usually require static (off-line) resource management. Due to the users interaction a very important among of multimedia applications require a dynamic control and a dynamic information manipulation. Thus, most multimedia processes may be considered as soft-real time processes [48].

A system of scheduling for the multimedia tasks must consider two goals in conflict:

- The processing of non critical processes should not suffer because of time critical process.
- A time critical process must never experience priority inversion.

In the majority of multimedia systems, attempts to solve real-time scheduling problems are variations on two algorithms: "Earliest deadline first" and "Rate monotonic" [35]. The majority of multimedia systems, which consider the tasks with pre-emption, use a variation of the algorithm "Rate monotonic".

5. PARADIGMS

The previous brief analysis of RT and MM systems leads to identify some important paradigms which are the basis of the different solutions used as well for RT as MM systems.

5.1 Synchronous vs asynchronous

The terms synchronous and asynchronous have several meanings according to their context of use. They may be applied to the physical layer, to the operating system level, to the application layer or even to the programming languages.
In real time applications, Kopetz (1990) introduces the concepts of « event driven systems » and of « time triggered systems ». They are respectively analog to the asynchronous and synchronous systems.
In MM systems, we speak of synchronous systems when it is needed that all participants must be presented at same time as in the so-called synchronous communication processes (Rendez-vous in ADA language). An example of this application class is the teleconferencing. Generally, we speak then of interactive applications that request real-time communication and synchronous transmission mode.
In other contexts, the synchronous transmission mode defines a maximum end-to-end delay for each packet of a data stream. This upper bound will never be violated. Moreover, a packet can reach the receiver at any arbitrary earlier time. Thus, an important claim of MM applications is satisfied: a maximal end-to-end delay can be guaranteed [35].
The other applications, when a maximum end-to-end delay is not required, are called asynchronous applications. In this case, it isn't necessary that all participants in communication are presented at same time. An example of this application class is the multimedia mail. In this case, an asynchronous transmission mode is acceptable. The asynchronous transmission mode provides for communication with no timely restrictions. Packet reach the receiver as fast as possible [35].

5.2 Periodic vs aperiodic

These terms qualify the application processes, the traffics, and by extension some protocols. Some processes are naturally periodic, others are periodically defined in order to simplify the application design. It depends on the considered external environment. The data acquisition of continuous information is based on the sampled systems theory and then managed by a periodic process. Some other information may be captured in any way from the operating system point of view, but at a given level, that is always managed by a periodic process.
In multimedia application it is possible to find tasks with both behaviours. For example, task such as *pause, stop, resume* are dynamic and are generated due to the user interaction (are a random behaviour) while that some control tasks (such as *play a record)* have a periodic behaviour.

5.3 Static vs dynamic

These terms qualify usually a lot of processes, distribution of the access right, objects definition, scheduling of tasks and of messages, introduction of nodes, ...

A process is said static when its behaviour is predefined before the application run-time. None decision is taken at the run time. It is dynamic when the behaviour is dynamically adapted to the state of the application at the run-time. These definitions are well suited for schedulings and for access distribution, but another definition must be introduced for some processes as the object definition in the stations. Such process is said static when it is impossible to be performed at the run-time.
In this case the terms off-line and on-line are respectively synonymous with static and dynamic.
In MM application it is possible to find both types of process. In MM applications where the interactivity is an important characteristics (conversational applications that request real-time communication mode), the workload is not known a priori (not predictible), and the process are dynamic (they are depending of the user's interactions).
In RT systems, both of the processes may be encountered, depending on the operating systems, on the languages, on the application services and protocol.

5.4 Determinism vs undeterminism

The determinism is based on the capability to predict something in the future from the knowledge of the past and of the present.
Even if this dilemma has been studied a lot by philosophers and scientists for several centuries, it is a very subject of discussion in computing systems, in networks and specially in real time and in multimedia systems .
The determinism doesn't exist in general if some hypothesis are not explicitely expressed, particularly in terms of reliability or dependability, of bounded delays, of absence of errors... However one can read sentences as « such protocol is a deterministic one ». Let us remember the discussions on Ethernet and the token techniques at the beginning of the eighties.
This paradigm must be essentially applied to the application behaviour whatever the environment may be.
It is always required that the whole application behaviour be deterministic as much as possible. But what is a deterministic behaviour ? Whatever the environment may be ? In all the cases of possible events ?
That's the problem of reliable or of fault tolerant systems design.
A misconception is to state that static processes, periodic behaviour, synchronous systems, lead to deterministic systems.
Guaranteed access to resources is certainly a better expression than determinism. It is very important in MM and RT systems. The real-time behaviour has to be maintained even in a *ìresource-overloadî* situation. Two main approaches are commonly used : the guaranteed services strategy for some of them, even in overload cases (but always under given hypothesis) and the best effort strategy for the other services.

6. MODELLING POINT OF VIEW

The principal works in MM and RT modelling are related with synchronisation aspects (representation of temporal and synchronisation constraints). Different techniques are used.

Petri-Nets: several variants of original Petri-Net model have been proposed to deal with synchronisation aspects and to represent the temporal behaviours. These solutions introduce explicit values of time in Petri nets. Some of these solutions are: Timed Petri-Nets (TPN), Arc time Petri-Nets (ATPN), Object Composition Petri-Net (OCPN) [11]. In special, the works of [11] [32] [14] [9] [12] [31] propose model definitions for the design of timed behaviours of multimedia distributed systems. These models are based on extensions of Petri net model: the TSPN (Time Stream Petri-Net). Also, [9] [12] [47] propose an extension of TSPN model for handling hypermedia documents: the HTSPN model (Hierarchical Time Stream Petri Net). In parallel Stochastic Timed Petri Nets are introduced in order to express probabilistic events, essentially in RT systems [20].
Object-oriented: various models have been proposed to represent multimedia data and multimedia communication aspects (in specially to model environments to multimedia design and programming, and to deal with operation in multimedia database systems). The term ìmultimedia objectsî refers to the data elements, such as video, audio, images, text, etc., which are used like objects in the programming object-oriented. [16] presents a synthesis about the different hierarchical classes that have been defined for multimedia objects. In general, the applications multimedia need to handle and manage several media objects at the same time, and then this relations are represented in using the composed objects. This aspect of composition is one of the causes of the diversity of models for the design of multimedia applications. Other works in this contexts are described in [8] [26] [42] [23].
In RT systems, object oriented approaches are used to define the application service element (in OSI sense). The main objective is to model the set of equipment to build interopable systems. Different kinds of objects are introduced (Function blocks, parameters, inputs and outputs, events, and so on), but the difficulty is to define the dynamic behaviours.

Others techniques: temporal graphs and languages-based model are another ways to express the synchronisation aspects in MM and RT contexts:

- *Temporal graphs technique* is used in multimedia modelling domain (to represent the temporal relations among multimedia information units and events). A graphs model permits to represent the temporal relationships as edges in a graph. In this model a temporal scenario is represented as a graph, where the nodes represent the event or object composing the scenario and the edges capture the temporal relationships among the components [4] [5].
- *Languages-based models.* In this context we can mention the works of [30] [5] [33] and [25]. [5] analyse the use of different languages, such as TCSP (Timed Communicating Sequential Process Language), LOTOS (Language of temporal Ordering Specification) and Hytime (Hypermedia/Time-based Document Structuring language), for the specification of continuous media synchronisation requirements and their temporal constraints in multimedia scenarios. [33] describe the use of formal specification languages, in specially the Z notation, to analyse the temporal knowledge underlying a multimedia presentation. [25] presents an unified representation of spatial relationships for multimedia objects. This model is based on Allen's temporal interval algebra. This model extend the Allen's algebra four directional relations to identify twelve directional relations (adding southwest, southeast, northwest, northeast, left, right, above, below). He introduces a set of rules to deduce other heterogeneous relations.

The principal differences that are presented in these models are:

- the representations of time,

- the objects that are represented (simple information units, more complex information entities), and
- the representation of single or complex relations among information units (simple occurrence of events at precisely defined instants, multiples events occurrence at same time, relationships between occurrences).

7. CONCLUSION

This paper has tried to analyse some similarities and differences between MM and RT systems. Both of MM and RT systems present time and synchronisation constraints and cooperation models.

The constraints are specified more or less explicitely according to the development tools and the operating systems, but if the specification is described with a formal approach, we may observe that the same models may be used, Petri Nets or automata variants, object oriented approaches, ... To manage these constraints, static or dynamic mechanisms may be used as the reservation of time slots or of bandwith, periodic and aperiodic traffics must be managed and the schedulings methods are common, synchronous and asynchronous approaches should be possible.

The cooperation or communication models are called differently but present very common principles.

The determinism is searched in both of the systems. To palliate the occurrence of faults, different techniques are used (running modes, renegociation of QoS) but they are similar in their spirit.

The types of networks used in these applications are often different, wide area networks for MM systems and local area networks for RT ones, but WAN are also more and more used in RT systems. And then the solutions developped for MM systems could be used for RT ones, essentielly at the transport and network layers.

The performances are also not the same, but the difference is decreasing with the use of MM systems in real time applications.

Finally, it seams interesting to study more in detail both of these systems in order to clarify the concepts, to define more generic solutions and a more common undestanding.

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