QoS Required by a DIS Application in a New Generation Internet

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Abstract : *In order to distribute new multimedia applications on a high scale, the mostly used and analyzed wide area networks (WAN) are the Internet on one side and ATM based networks on the other side. One of the current research activities in the networking area consists in trying to federate the Internet new mechanisms / protocols (IP new Generation : IPnG) and the ATM ones, in order to allow applications to be guarantied with an end to end Quality of Service (QoS). Study which is presented in this paper dills with this specific activity and has been realized within a project implying a French Industrial (Dassault Electronique) and three French research Laboratories (LAAS-CNRS, LIP6) and Institute (INRIA Sophia Antipolis)[1] ; the general goal of the project was to specify and then perform the QoS required by a distributed interactive simulation (DIS application) in an heterogeneous WAN environment : IPnG and ATM (national MIRIHADE platform, today SAFIR). Results exposed in this paper are mainly related to the QoS characterization a DIS application has to require so as to be distributed in a WAN environment ; a shorter part of the paper is dedicated to the end to end communication architecture defined within the project in order to provide a QoS matching DIS applications requirements.*

1. Introduction

1.1. Work context

These latest years, technological improvements in both computer science and telecommunications areas led to the development of new distributed multimedia applications implying processing and (differed or in real time) transmission of all media kinds. Communication requirements of such applications make it necessary the use of new networks providing both high speed transmissions and guaranteed qualities of service (QoS) : throughput, transit delay, etc. Among these applications, *distributed interactive simulation* (DIS) applications have specific features (interactivity, hard time constraints, …) that make it difficult both their traffic characterization and the QoS specification to require from the network.

In order to distribute these new applications on a high scale, the mostly used and analyzed wide area network (WAN) solutions are the Internet on one side and ATM based networks on the other side.

- In spite of (or due to) its popularity, the current Internet does not allow an adequate treatment of multimedia applications features and requirements ; these latest years, several works have been initiated so as to solve the problem : particularly, the Integrated Service (*IntServ*) working group [i] of the IETF (Internet Engineering Task Force) has recently proposed some extensions of the current Internet service model [ii][iii], and also published lots of papers related to mechanisms

[1] LAAS-CNRS : Laboratoire d'Analyse et d'Architecture des Systèmes du Centre National de la Recherche Scientifique
LIP6 : Laboratoire d'Informatique de l'Université de Paris VI
INRIA Sophia Antipolis : Institut National de Recherche en Informatique et en Automatique de Sophia Antipolis

and protocols [iv][v] allowing to perform the newly defined services.

- On the other side, several local ATM platforms have been developed in different places, particularly in France in three research laboratories : the LAAS/CNRS (Toulouse), the INRIA (Sophia Antipolis) and the LIP6 (Paris) ; in 1997, the interconnection of these platforms led to the born of the MIRIHADE platform (today SAFIR) on which several experiments have been performed (performances measurements, multimedia applications testing, etc. [vi]).

One of the main research activities in the network area consists in trying to federate Internet and ATM worlds in order to provide applications with end to end guaranteed QoS, independently of the used physical networks. The study exposed in this paper dills with this specific activity and has been realized within the "DIS/ATM" project[2] implying a French industrial (Dassault Electronique) and the three previously cited laboratories (LAAS/CNRS, INRIA and LIP6).

The general goal of the project was to specify and then perform the QoS required by a DIS application in a WAN environment implying the Internet new Generation (IPnG) and ATM. Within the project, LAAS-CNRS has been mainly implied in the following three parts :

1. characterization of the QoS a DIS application has to require so as to be distributed in a WAN environment ;
2. design of an end to end communication architecture :
   – providing a QoS matching DIS applications requirements ;
   – distributed over an Internet version 6 (IPv6) network environment, able to provide the IETF *Intserv* service models (*Guaranteed Service* and *Controlled Load*);
3. integration of the targeted DIS application within this architecture in a PC/Linux machine/system.

1.2. Paper Content

Results exposed in this paper are mainly related to the first of the previous points : characterization of the QoS a DIS application has to require so as to be distributed in a WAN environment.

The following of the paper is structured as follows : the major part of the paper (section 2) consists in an analysis of the end to end QoS a DIS application has to require in WAN environment, in order to be *coherently*[3] distributed ; more precisely, we first show the DIS standard QoS specification limits when the application is distributed in a WAN environment ; in a second step, a solution allowing to solve the enounced limits is given. The third part of the paper (section 3) proposes a DIS PDUs[4] classification that matches application requirements, but also allows the design of an end to end communication architecture based on an architectural principle mainly applied these latest years in the multimedia architecture context. The fourth part of the paper presents an overview of the defined end to end architecture (section 4). Finally, conclusions and future works are presented in section 5.

2. DIS Applications and Networking QoS

The goal of this section is to define the QoS a DIS application has to require from a WAN (such as IPnG) so as to be *coherently* distributed through the network.

Following this goal, we first show the DIS standard QoS specification limits in a WAN environment. Then, another QoS expression is proposed allowing to solve the problems associated to the previous limits. More detailed information related to this work may be consulted in [vii].

Note : Several work themes performed within the DIS context are not presented in this paper. Readers may consult [viii][ix][x][xi][xii][xiii] to get more information about these themes.

2.1. Coherence notion

Traffic generated by a DIS application may be divided into three parts :

- traffic corresponding to the broadcasting of the simulated entities state (*Entity State* PDU, etc.) and events (*Fire* PDU, *Detonation* PDU, *Collision* PDU, etc.) ;
- traffic corresponding to the communication between participants or exchanges between captors : radio communications (*Signal* PDU) and electromagnetic interactions (*EM-emission* PDU, etc.) ;
- traffic corresponding to the distributed simulation management : simulation initialization, participants

[2] The DIS/ATM project (convention n° 97/73-291) is co-financed by the French MENRT (Ministère de l'Education Nationale, de la Recherche et de la Technologie) and the DGA (Direction Générale de l'Armement).

[3] This term will be defined in the appropriate section (section 2).

[4] PDU : Protocol Data Unit

synchronization, … (*Start* PDU, *Resume* PDU, etc.).

With regard to the DIS standard [xiv][xv][xvi], a DIS application is correctly distributed if any simulation site has both a *temporal* and a *spatial coherent view* of the distributed simulation ; in other words, this means that :

- any event (fire, detonation, …) occurred at time t_0 on a given site has to be known by the other sites at least T time units after the date t_0 (temporal coherence) ;
- the state (position, orientation, …) of any entity simulated on a given site has to be "almost" identical to the one extrapolated on any other site (by application of the same *dead reckoning* algorithm), the "almost" term meaning that the difference between those two states has to be less than a maximal value defined as the *threshold* value in the DIS standard (spatial coherence).

In order to illustrate this second point, let's consider the example of an entity A representing a fly simulated on a site S_1. At a given time, another site S_2 has a spatially coherent view of A if the difference between the knowledge $S2$ has from the state of A and the real state of A (i.e. the one simulated on site S_1) does not exceed a given *threshold* value*,* defined in the DIS standard as the maximal acceptable error done on the position (Th_{Pos}) and the orientation (Th_{Or}) on each entity.

The underlying Figure 1 illustrates on a same plan the position and the orientation of the entity A (supposed here to be a fly), respectively on site S_1 (fly on the left) and on site S_2 (fly on the right). While the position error E_p and the orientation error E_o do not exceed their respective threshold (Th_{Pos} and Th_{Or}), $S_1$and S_2 have a spatially coherent view of A. Out of one of those thresholds, it is necessary for S_2 to refresh the state of A by means of a state information sent by S_1 (typically an *Entity State* PDU).

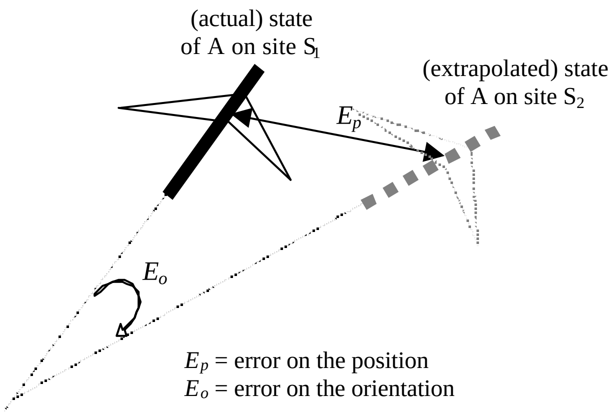

Figure 1 : Position and orientation of an entity

2.2. DIS standard QoS specification

As they are expressed within the DIS standard, DIS application requirements are the following ones :

- the application has to be provided with a multicast transport level service ;
- QoS associated with the end to end DIS PDUs transport is defined by means of three parameters whose value depends on the *coupling* of the corresponding entities with the other entities :
  - reliability, defined as the maximal PDU loss rate ;
  - maximal end to end transit delay ;
  - maximal jitter for radio type PDUs.

Let's first recall the *coupling* notion.

Assume A be an entity simulated on a given site. According to the DIS standard, one of the two following situations may to be identified : (1) A is *loosely coupled* with all other entities or (2) A is *tightly coupled* with at least another (local or distant) entity. As an example (given in the standard) :

- Two distant tanks (5 kilometers between them) provide an example of loosely coupled entities ;
- Several tanks in formation at a fast speed provide an example of tightly coupled entities.

From this situation, QoS associated with the transfer of the *Entity State* PDUs is defined as it follows :

- a transit delay less than or equal to 100 milliseconds (ms) and a loss rate less than or equal to 2 % is required for the transfer of PDUs associated with tightly coupled entities ;
- a transit delay less than or equal to 300 milliseconds (ms) and a loss rate less than or equal to 5% is required for the transfer of PDUs associated with loosely coupled entities.

2.3. DIS standard QoS specification limits

Two major limits may be identified from the previous QoS specification :

- **(L1)** First, it does not allow the design of an end to end architecture based on a several time applied architectural principle [xvii][xviii][xix][xx] : " one end to end channel per user flow, providing a specific QoS associated with the features and the constraints of the transported flow ".
- **(L2)** The second limit results in the impossibility to make it possible the respect <u>at any time</u> of the simulation spatial coherence.

Let's detail this second affirmation.

Assume two sites S_s and S_r belonging to the same DIS exercise ; S_s and S_r are supposed to be perfectly synchronized. Assume now an entity *A* simulated on site S_s, whose state is maintained on site S_r by application of a *dead reckoning* (DR) algorithm. In order to simplify future explanations, *A* state will be reduced in the following to the position of *A* according to only one dimension.

The underlying Figure 2 illustrates on a same plan evolution in time of the extrapolation error[5] *E* made on *A* position, respectively on site S_s (superior part of the figure) and on site S_r (inferior part of the figure) ; both sites are supposed to have a same reference time and to apply a same DR algorithm. Let's also recall that only S_e is able to calculate the real state of A.

Black (respectively gray) plumps on Figure 2 correspond to the sending *Ts* dates (respectively receiving *Tr* dates) of the *entity state* (ES) PDUs refreshing *A*. We suppose that the time origin corresponds to the sending date of the first ES PDU (Ts_0). Thus, Tr_0, Tr_1, Tr_2 and Tr_3 correspond to the receiving dates of the ES PDUs sent at Ts_0, Ts_1, Ts_2 and Ts_3.

[5] The extrapolation error *E* is obviously defined as the geometrical difference between the actual and the "dead reckoned" state of the considered entity.

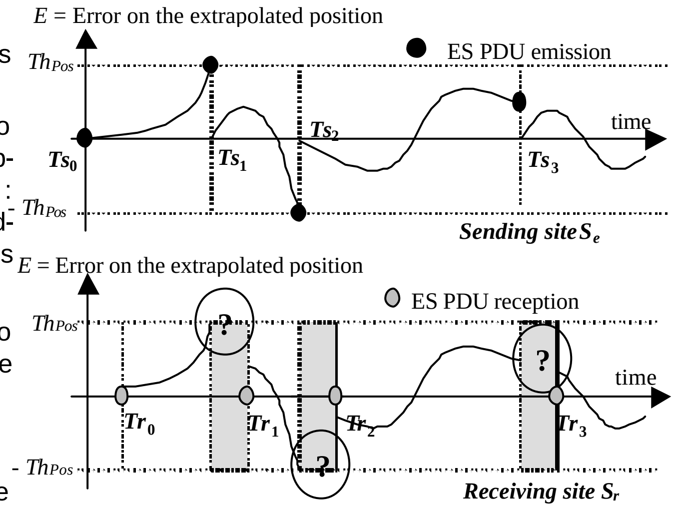

Figure 2 : Extrapolation error evolution

Let's analyze Ts_1, Ts_2 and Ts_3 dates.

- Starting from Ts_0, the error *E* between the extrapolated and the actual position of *A* is growing up (in absolute value) and raises its maximal acceptable value (Th_{Pos}, corresponding to the position *threshold* value) at Ts_1 : at this time, an ES PDU is generated by S_s (DR application), indicating the actual position of *A* ; error *E* becomes null on site S_s.
- Starting from Ts_2, the error *E* between the extrapolated and the actual position of *A* varies between ($-Th_{Pos}$) and ($+Th_{Pos}$) without exceeding one of those two values ; after a *Heart Beat Timer* (HBT) spent time, i.e. at $Ts_3 = Ts_2 + 5$ second (default value for the HBT in the DIS standard), an ES PDU is automatically generated by S_s, indicating as in the previous case the actual position of *A* ; error *E* becomes null on site S_s.

Let's now analyze the evolution of error *E* on site S_r.

- Starting from Ts_0, the error *E* between the extrapolated and the actual position of *A* is identical to the one on S_s ; particularly, *E* raises its maximal acceptable value Th_{Pos} at time Ts_1, corresponding to the ES sending date on S_s. However, *A* position is not updated before Tr_1, the time interval separating Ts_1 from Tr_1 corresponding to the ES PDU transit delay through the network. Consequently, it then appears an indetermination on *E* value between Ts_1 and Tr_1 : during this time period, *E* may exceed the Th_{Pos} value, and then potentially generate a spatial coherence violation.

- Analogously, a same indetermination may occur between Ts_2 and Tr_2, and between Ts_3 and Tr_3, illustrated on Figure 2 by the gray zones.

It results from this analysis that the current standard QoS definition makes it possible a spatial coherence guaranty <u>except eventually</u> during each [Ts_i, Tr_i] time interval : during those time periods, the error E may transitorily exceed in absolute value the maximal acceptable value (DIS standard *threshold*). Such a case is illustrated on Figure 3.

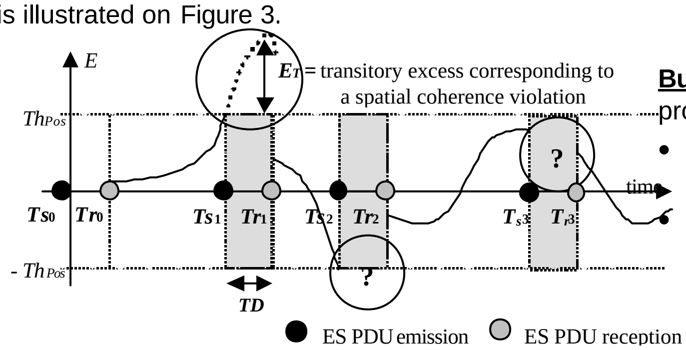

Figure 3 : Transitory excess illustration

Two questions may then be raised :

1. Is this phenomenon a problem for a DIS exercise ?
2. In this case, is it possible to solve the problem ; in other words, is it possible to keep the transitory excess E_T illustrated on Figure 3 under a given value ?

As far as the first question is concerned, the transitory excess becomes problematic as soon as the transit delay (*TD* on Figure 3) is non negligible regard with the mean time interval separating two ES PDU consecutive receptions. In this case, it then results that the receiving sites may have an incoherent view of the simulation during non negligible time periods, and even " almost all time " if the refreshing period is negligible compared with the ES transit delay ; of course, this risk does not occur in a LAN environment, but has to be taken into account when the application is distributed in WAN environment such as the one considered in our study.

As far as the first question is concerned, we now formulate a QoS proposition aimed at allowing the respect of a maximal transitory error value.

2.4. QoS proposition

In order to solve the previous two limits (L1 and L2), the QoS specification that is proposed is based on the followings points :

- as in the DIS standard, the application has to be provided with a multicast transport level service ;
- QoS associated with the end to end DIS PDU transport is defined by means of the same three parameters than the ones defined in the DIS standard :
  - reliability, defined as the maximal PDU loss rate (total reliability meaning a 0 % loss rate ; null reliability meaning that a 100 % loss rate is acceptable) ;
  - maximal end to end transit delay (possibly infinite) ;
  - maximal jitter for radio PDU ;

<u>But</u> and differently from the standard specification, we propose :

- to give up the *coupling* notion which is used in the standard to define QoS parameter values ;
- to evaluate QoS parameters value :
  - so as to guaranty <u>at any time</u> that the extrapolated and the actual state of any simulated entity do not differ from each other beyond a maximal value ; in that, we provide an answer to limit **(L2)**.
  - only from the information contained in each PDU ; in that, we provide an answer to limit **(L1)** ;

Let's now study how the announced guaranty can be performed. More exactly, let's study how the transitory excess E_T illustrated on Figure 3 may be kept under a maximal value.

2.5. Transitory excess control mechanism

Consider the underlying Figure 4. Obviously, the transitory excess E_T may be kept under a maximal E_{Tmax} value as soon as the ES PDUs transit delay does not exceed the TD_{max} value illustrated on the figure.

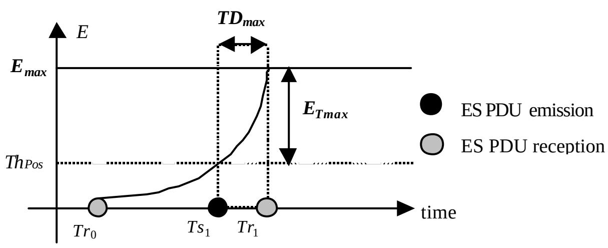

Figure 4 : Transitory excess control

Intuitively, it is possible to conceive that E_T value depends on the dynamic (i.e. the acceleration) of the corresponding entity : the higher this dynamic, the higher E_T (potentially). Consequently, one can also conceive that E_{Tmax} value also depends on the entity dynamic.

Let' now formalize this approach of the problem.

On each receiving site, the influence of the transit delay (*TD*) on the extrapolated state of a distant entity is related to the difference (in absolute value) $e_{\mathbf{P}}(t)$ between the actual position $\mathbf{P}_a(t)$ and the extrapolated position $\mathbf{P}_{DR}(t)$ of the considered entity (relation 1).

$$(1)\quad \begin{cases} \mathbf{P}_a(t) = \int_{Ts_i}^{t} du \int_{Ts_i}^{u} \mathbf{A}_a(t)\cdot dt + (t - Ts_i)\mathbf{V}_i + \mathbf{P}_i \\ e_{\mathbf{P}}(t) = \left\|\mathbf{P}_a(t) - \mathbf{P}_{DR}(t)\right\| = \left\|\int_{Ts_i}^{t} du \int_{Ts_i}^{u} \left[\mathbf{A}_a(t) - \mathbf{A}_i\right]\cdot dt\right\| \end{cases}$$

where :

- $\mathbf{A}_a(t)$ gives the actual acceleration of the considered entity at time t ;
- $\mathbf{P}_i$, $\mathbf{V}_i$, and $\mathbf{A}_i$ respectively give the actual position, speed and acceleration of the entity at time Ts_i.

Let's note that $\mathbf{P}_i$, $\mathbf{V}_i$, and $\mathbf{A}_i$ are three specific fields of the ES PDU sent at time Ts_i.

If the entity has a bounded acceleration ($\|\mathbf{A}_a(t)\| \leq A_{\max}$), then $e_{\mathbf{P}}(t)$ can be bounded during each $[Ts_{i+1}, Ts_{i+1}+TD]$ time interval.

$e_{\mathbf{P}}(t)$ being less than or equal to Th_{Pos} while $t \leq Ts_{i+1}$, it is then possible to major $e_{\mathbf{P}}(Ts_{i+1}+TD)$ by a sum of three terms (relation 2) :

$$(2)\quad \begin{aligned} e_{\mathbf{P}}(Ts_{i+1}+TD) \leq & \left\|\int_{Ts_i}^{Ts_{i+1}} du \int_{Ts_i}^{u} \left[\mathbf{A}_a(t) - \mathbf{A}_i\right]\cdot dt\right\| \\ & + \left\|\int_{Ts_{i+1}}^{Ts_{i+1}+TD} du \int_{Ts_i}^{Ts_{i+1}} \left[\mathbf{A}_a(t) - \mathbf{A}_i\right]\cdot dt\right\| \\ & + \left\|\int_{Ts_{i+1}}^{Ts_{i+1}+TD} du \int_{Ts_{i+1}}^{u} \left[\mathbf{A}_a(t) - \mathbf{A}_i\right]\cdot dt\right\| \end{aligned}$$

- Following the *dead reckoning* mechanism on the sender site, the first term is obviously majored by Th_{Pos}.
- The third term is majored by :
  - (½) $A_{\max}$. TD^2 for a linear extrapolation ($\mathbf{P}_{DR}(t) = \mathbf{P}_i + \mathbf{V}_i.(t - Ts_i)$)
  - $A_{\max}$. TD^2 for a quadratic extrapolation ($\mathbf{P}_{DR}(t) = \mathbf{P}_i + \mathbf{V}_i.(t - Ts_i) + \frac{1}{2}\mathbf{A}_i.(t - Ts_i)^2$)
- It is then to major the second term, corresponding to the product between *TD* and a constant representing the difference between the entity actual speed and its extrapolated speed at time Ts_{i+1}, sending date of the ES (relation 3) :

$$(3)\quad \begin{aligned} & TD \cdot \int_{Ts_i}^{Ts_{i+1}} \left[\mathbf{A}_a(t) - \mathbf{A}_i\right]\cdot dt \\ & = \left[(\mathbf{V}_{i+1} - \mathbf{V}_i) - \mathbf{A}_i \cdot (Ts_{i+1} - Ts_i)\right]\cdot TD \\ & = \left(\mathbf{V}_a(Ts_{i+1}) - \mathbf{V}_{DR}(Ts_{i+1})\right)\cdot TD \end{aligned}$$

This difference raises its maximal absolute value when the difference between the entity actual speed and its extrapolated speed is also maximal during the whole $[Ts_i, Ts_{i+1}]$ time interval.

Under those conditions, the second term of relation (2) is majored by $\sqrt{2A_{max}\cdot Th_{Pos}}\cdot TD$ for a linear extrapolation and by $2\sqrt{A_{max}\cdot Th_{Pos}}\cdot TD$ for a quadratic expression.

As a conclusion, it is then possible to major $e_{\mathbf{P}}(t)$ by the following expression (relation 4) :

$$(4)\quad e_{\mathbf{P}}(t) \leq \begin{cases} \left(\sqrt{Th_{Pos}} + TD\cdot\sqrt{\frac{1}{2}A_{max}}\right)^2 & \text{for a linear extrap.} \\ \left(\sqrt{Th_{Pos}} + TD\cdot\sqrt{A_{max}}\right)^2 & \text{for a quadratic extrap.} \end{cases}$$

In order to keep the transitory error E_T under a maximal E_{Tmax}, value, it is then necessary and sufficient to guaranty for each ES PDU a maximal end to end transit delay whose value is given by the following expressions (relation 5) :

$$(5)\quad TD_{max} \leq \begin{cases} \dfrac{\sqrt{Th_{Pos}+E_{Tmax}} - \sqrt{Th_{Pos}}}{\sqrt{0{,}5\cdot A_{max}}} & \text{for a linear extrap.} \\ \dfrac{\sqrt{Th_{Pos}+E_{Tmax}} - \sqrt{Th_{Pos}}}{\sqrt{A_{max}}} & \text{for a quadratic extrap.} \end{cases}$$

In other words, it is then possible to ensure a spatial coherence guarantying the entity position inside a uncertainty circle whose radius is Th_{Pos} + E_{Tmax}, provided by the ES PDUs end to end transit delay is less or equal than TD_{max}.

The previous discussion may be easily extended to the case of an extrapolation on the orientation. Results are similar, but provide more complex expressions due to the rotation matrix.

Let's finally note that :

- for a given Th_{Pos} + E_{Tmax}, if Th_{Pos} decreases, then TD_{max} grows up : temporal constraints are then easier to satisfy (from the network point of view), but ES PDUs are sent more frequently (the throughput grows up) ;
- the TD_{max} value is smaller with a quadratic extrapolation than with a linear one ; consequently, temporal constraints are then more difficult to satisfy (from the network point of view) but ES PDUs are sent less frequently.

In both cases, relation (5) allows to deduce the transit delay expected from the underlying network, from features and constraints (acceleration and thresholds) expressed at the application level. Furthermore, this is accomplished without any modification of the standardized DR algorithm : the sending of an ES PDU occurs when the extrapolation error value (for the position or the orientation) goes beyond a fixed threshold. A modification of this sending criterion (by adding a threshold mechanism for the speed or the acceleration) may result in a reduce of either the generated ES PDU number or the required temporal constraints.

3. DIS PDU Classification

Starting from this QoS proposal, a DIS PDU classification is now formulated. Two goals are pursued within this classification :

- the respect <u>at any time</u> of the simulation coherence ;
- the design of an end to end architecture based on a well known architectural principle for the support of multi-flow applications (such as multimedia applications) : "establishment of an end to end channel providing a specific QoS for each application level flow".

Four classes have been defined, the fourth one being subdivided into sub-classes :

- **The *discrete* PDU class** (*Collision*, *Fire* and *Detonation* PDU), that requires as QoS parameters :
  - a total reliability ; such a QoS results from the *discrete* feature of the concerned PDUs that makes it impossible their extrapolation ; as an example, if a *Fire* PDU is lost, the associated information could not be deduced from the next received PDU (at the opposite of *Entity State* PDUs) ;
  - a maximal end to end delay associated with the willed interactivity (we kept the100 millisecond (ms) recommended by the DIS standard for PDUs whose associated entity is in strong interaction with at least another one).
- **The simulation management PDU class** (*Start*, *Stop*, … PDU), that requires as QoS parameters :
  - a total reliability ; indeed, as they are defined in the DIS standard, PDU exchange rules do no precise the DIS software behavior when a simulation management PDU loss occurs : implicitly, the underlying network is supposed to be perfectly reliable ;
  - an unbounded end to end transit delay (no specific temporal constraint).
- **The signal PDU class** (only one PDU : the Signal PDU), that requires as QoS parameters :
  - a "strong" reliability depending from the audio coding algorithm ;
  - a 250 ms maximal transit delay ms, corresponding to the value recommended for a real time distributed audio conferencing system ;
  - a 50 ms jitter as it is specified in the DIS standard.
- **The *continuous* PDU class** (essentially *Entity State* PDU) that requires as QoS parameters :
  - a total reliability (implicit hypothesis in the previous TD_{max} calculation) ;
  - a maximal end to end transit delay, deduced from the previous relation (5) ; as a consequence, several sub-classes are defined that we summarized Figure 5.

A_{max} TD_{max}

A_{max} domain	Guaranteed DT_{max}
$[0, A_1]$	TD_1
$[A_1, A_2]$	TD_2
…	…
$[A_{n-1}, A_n]$	TD_n

Figure 5 : Entity State PDU classification

At each maximal acceleration $[A_{i-1}, A_i]$ interval is associated a maximal transit delay allowing a spatial coherence respect for entities whose maximal acceleration is comprised between A_{i-1} and A_i.

4. The End to End Resource Reservation Architecture

Starting from the previous results, our second goal was to design an end to end architecture allowing DIS applications to be distributed with respect to the QoS defined for each of the defined PDU class.

In order to perform this goal, two preliminary needs had been identified :

- the availability of a network providing both a multicast transfer and QoS guaranties ; within the project, the chosen network has been the Internet new Generation through (1) the IETF *Intserv* service models (*Guaranteed Service*, *Controlled Load*), (2) a traffic control similar to the Class Based Queuing (CBQ) one and (3) the RSVP protocol ;
- a characterization of the DIS traffic generated by each site, so as to provide the network with elements required to perform the resource reservation phase.

Remind that this paper is not dedicated to the end to end architecture (readers may consult [vii][xxi] to get more information on this part of our work) ; consequently, only the main hypothesis and principles are exposed in this section.

4.1. Traffic characterization principles

The traffic characterization methodology is based on the basic principle that a global DIS traffic may be considered as the aggregation of individual traffics generated by identifiable application level elements (AE) (Figure 6).

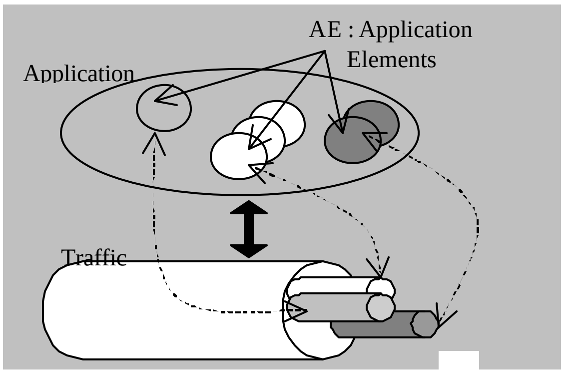

Figure 6 : Global traffic vs. individuals ones

More precisely, three hypothesis are underlying to the defined methodology.

- **H1** : AEs must be identifiable ; in other words, application might be decomposable into several autonomous parts, each generating its own traffic ; in the DIS application context, AEs identified on a given site have been chosen as the entities (locally simulated) whose *morphology*[6] is the same ; this choice has been validated experimentally.
- **H2** : So as to be statistically reproducible, traffic generated by each AE must depend on application intrinsic parameters ; if these hypothesis seems to be verified in a DIS context (through the basic idea : "each entity or entity group generates an individual and well characterized traffic"), interactivity between the simulated entities may result in a traffic evolution. This aspect has not been tackled in our study and consists in a future work ;
- **H3** : it exists a correlation between AE individual traffics and the global traffic generated by their composition. At the current time, we only assume this hypothesis valid, without no more demonstration.

From those hypothesis, the applied methodology consists in the following points.

- We first developed a few software's allowing to capture and isolate the DIS traffic corresponding to each identifiable morphology.
- We then generated a reproducible DIS traffic by means of a public software named *DIS Control Station (DIS-CS)* [xxii].
- By means of simple software's allowing to calculate RSVP *Tspec* parameters for a given traffic, the *Entity State* traffic generated by each identified DIS morphology has finally been characterized in order to constitute a Traffic Information Base (TIB).

Knowing morphology and number of the locally simulated entities, it is then possible (by means of the previous TIB) to evaluate the ES PDUs initial traffic generated by a given site.

4.2. End to end architecture design principles

Starting from the previous results (QoS and TIB constitution), the end to end architecture defined within the project (Figure 7) relies on the following principles.

- Applying a principle several times used in the design of end to end multimedia architecture [xxiii][xxiv][xxv][xxvi], a DIS+ level multicast channel (aimed at providing a specific QoS) is established for each identified PDU class.
- A reservation process is then executed in order to make it effective the QoS guaranty on each opened channel. This *static*[7] process is made up of two different steps :
  - (1) for each sender : the specification of the to be generated traffic profile ;
  - (2) for each receiver : the resource reservation.

[6] The term *morphology* is defined in the DIS standard as a "set of header fields describing both the physical appearance and behavior of one simulated entity" . More precisely, a morphology is composed of eight fields : *Entity, Kind, Domain, Country, Category, Subcategory, Specific* and *Extra* ; we only keep the first four in our experiments.

[7] *Static* meaning " without re-negotiation " after the beginning of the simulation.

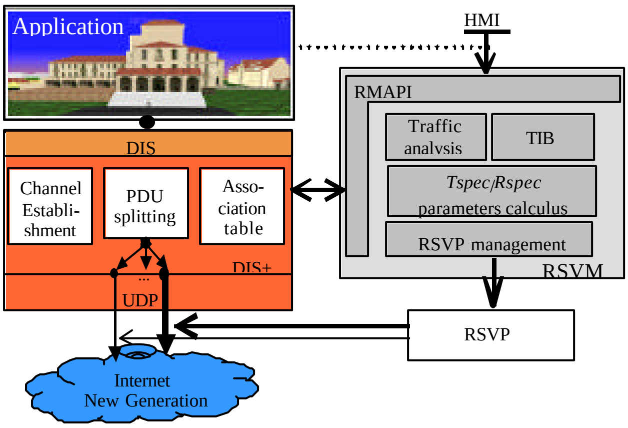

Figure 7 : The end to end architecture

Two different problems are then to be tackled :

- **channels management**, meaning :
  - channels establishment ;
  - DIS PDU splitting and de-splitting in and from the adequate channel.
- **QoS control of each channel**, part dedicated to a Resource reSerVation Manager : the RSVM module illustrated in Figure 7, whose main functions are the following ones.
  - The first function of the RSVM is to make it possible for the DIS application the specification of its traffic (via an RSVM level API[8] or an HMI[9]) in terms of owner oriented parameters rather than network oriented ones (typically : RSVP *Tspec* parameters). More precisely, these terms are the *morphology* and the *number* of the locally simulated entities.
  - The second function is to translate application parameters in terms of *Tspec* parameters ; to perform this task, the RSVM uses a *Traffic Information Base* (TIB), containing the <morphology , *Tspec*> associations as they have been deduced from the DIS traffic characterization. The TIB is basically achieved in a calibration phase occurring before any DIS exercise ; however, it can also be upgraded during a DIS exercise by the way of probes measuring the exchange traffic.
  - The third function is to manage RSVP so as to establish one RSVP session with the adequate QoS (i.e. corresponding to the one required for the transported PDU class) per opened channel.

[8] API : Application Programming Interface
[9] HMI : Human Machine Interface

This architecture has been implemented in order to make it possible the project contractual demonstrations.

5. Conclusions and Future Works

This paper has presented part of the work performed within the DIS-ATM project whose general goal was to specify and then perform the QoS required by a DIS application in a WAN environment implying the Internet New Generation (*Intserv* service models, associated traffic control mechanisms, RSVM) and ATM.

The major part of the paper dills with DIS application requirements and QoS specification (section 2 and 3) ; results exposed in those two sections may be summarized in three points :

- the first one concerns the DIS standard limits as far as the QoS specification is concerned ; indeed, in its current state, this specification does not guaranty the simulation coherence in a WAN environment ; moreover, it does not allow the design of an end to end architecture based the architectural principle “one channel with a specific QoS for each application level data flow” ;
- the second result dills with a QoS specification proposal allowing to solve the previous two limits ;
- the third result consists in a DIS PDU classification, each class requiring a specific QoS whose parameters value have been given.

On the basis of these results, the end to end architecture defined to satisfy the previous QoS has been summarized in section 4. In the first part of the section, a methodology allowing a *Tspec* characterization of DIS traffics has been introduced. In the second part of the section, the end to end architecture has been exposed.

Different kinds of perspectives are currently studied ; the main three are the following ones :

- The first one consists in the experimental validation of the architecture through two different aspects : (1) traffic characterization methodology validation and (2) QoS respect. More precisely, the goal of the first work is to prove that the initial traffic generated by a given DIS application conforms the “a priori” estimate *Tspec*. The second work is based on already performed measures (not presented in the article) showing that the QoS defined in the first part of the paper is not ensured when the application is distributed in the DIS/ATM project network environment without resource control ; architecture validation (as far as QoS respect is concerned) is currently performed by means of analogous measures now performed in the project network environment implementing resource control.

- The second perspective is to tackle the major architecture drawback : its static aspect. At the current time, once resources have been associated to the defined end to end channels, no modification occurs in the network even if DIS traffic varies (due to entity death or new entity creation). It is then our purpose to specify a resource reservation renegotiation phase.
- The third perspective is to extend the proposed architecture in order to take into account a more general application / network environment context, including other real time applications and other Internet service models.

The last two perspectives are envisaged within a new project whose main goals are to extend and generalize results obtained within the DIS/ATM project.

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