PERFORMANCE ANALYSIS OF RSVP BASED DISTRIBUTED MEASUREMENT SYSTEMS

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Abstract - *In this paper the performance of a RSVP-based distributed measurement system prototype is analysed and compared with one ordinary RSVP-less. After some hints on RSVP, the software and hardware architecture of the prototype is described. The methodology for Quality of Service measurement on IP network is used in order to analyse and compare the performance of the prototype realised in the laboratory. Moreover, aspects concerning the distributed measurement system security are examined and the adopted security policy is discussed.*

Keywords - Internet, Measurement, RSVP, Real-time.

1. INTRODUCTION

This paper aims to propose a real-time measurement and control system over Internet and to make an analysis of its performance. Until now, when the monitoring and control of industrial systems and ongoing processes with hard delay bounds were required, the proposed architectures were limited to the intranet. In the measurement and control field all proposed distributed architectures over Internet result effective only when no strict delay bounds are present [1-6]. These architectures, with regards to the communication aspect, are based on the traditional TCP/IP protocol, which assures the delivery of data but cannot guarantee deadlines.

The basic idea is the development of a real-time distributed architecture, based on the ReSerVation Protocol (RSVP), to be deployed over the Internet. The challenge of real-time communication over the Internet and the Quality of Service (QoS) have recently addressed. The RSVP, which should guarantee the QoS was proposed in [7], and research efforts were focused on the development of a standard for the QoS interface [8-10]. The possibility of guaranty QoS over the Internet opens new horizons, especially in the critical fields of measurement and control systems.

The first prototype of a RSVP-based distributed measurement and control system was implemented at the Laboratory for Signal Processing and Measurement Information (LESIM) at the University of Sannio, Benevento, Italy. This system is aimed to the monitoring and control of a small industrial system emulator [11]. This paper shows the performance of the RSVP-based distributed measurement system. Both the methodology for QoS measurement on IP-network and aspects concerning the distributed measurement system security are examined. A description of the set of the parameters established to have a clear picture of the QoS of the particular network is given. Attention is focused on the measurement of these parameters and on the comparison between RSVP-based distributed measurement prototype and RSVP-less realised in the laboratory. Moreover, security considerations and security policy for the RSVP based distributed measurement systems are given. A description of the adopted security policy for the prototype realised is also reported.

2. SYSTEM ARCHITECTURE

The measurement and control system is shown in Fig.1. In order to emulate the Internet, two LANs (Local Area Networks) are connected in the laboratory using two CISCO 1750 routers which support the RSVP protocol. On one side, the measurement server is connected to the LAN1, and on the other side the monitoring client is connected to the LAN2.

The measurement server periodically acquires data from the industrial system emulator through an acquisition board PCI6023E and sends these to the monitoring client. It can also actuate control of the industrial system when this is required by the client. The industrial system emulator is here represented by a simple water tank, where both water level and temperature have to be maintained within a predetermined range (Fig.2). The water tank is equipped with a boiler and a small pump. An ultrasound transducer and a thermocouple are used in order to enable the detection of both fluid level and temperature. Five digital output channels of the PCI6023E board are necessary for actuating control of the industrial emulator. Two analogue input channels are used to acquire the water level and temperature.

The RSVP protocol supported by the routers reserves the necessary bandwidth on the routers and ensures that priority is given to the transmitted data packets in the internal router’s queues. The main advantage of using the RSVP is the guaranteeing of deterministic behavior on the Internet and satisfaction of the strict delay bounds necessary for real–time control applications.

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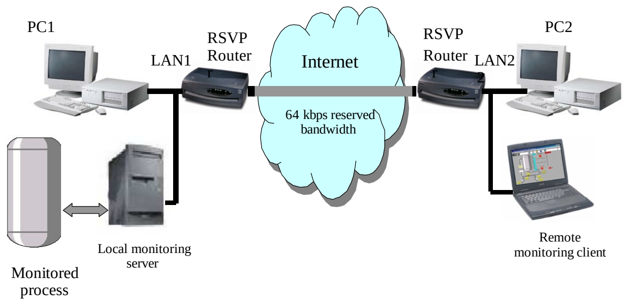


Fig.1 - Prototype of RSVP based distributed measurement and control system.

In order to simulate ordinary Internet status, in addition to the server and client, other independent traffic sources and receivers are included.

3. SOFTWARE ARCHITECTURE

The proposed software architecture is shown in Fig.3. This architecture is modular in order to individuate and make independent the main parts of the system [12]. It is possible to refigure four modules: *Instruments, Measurement Procedure Manager, Data Store Manager, Communication Administrator*.

The *Measurement Procedure Manager* executes a measurement procedure on the server side. Basically, it executes a measurement loop in which it interacts with (i) the *Instruments* for data acquisition and command actuation, (ii) the *Communication Administrator* in order to send data to the client and to receive the user's commands, and (iii) the *Data Store Manager* for the storing of data necessary for further statistical elaboration.

The measurement loop is deterministic with regard to the time duration of each cycle composed by (i) a request to the acquisition board for either the acquisition of data or command actuation, (ii) effective data acquisition or command actuation, (iii) eventual data elaboration, and (iv) data storage if required.

The main problem when remote control through the Internet is requested is to ensure that data and commands are transmitted

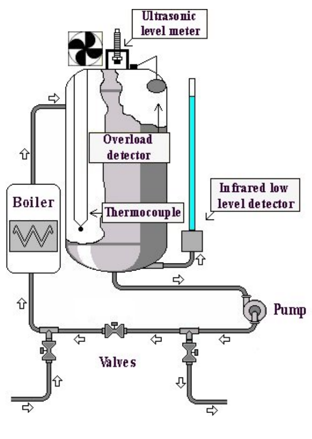


Fig.2 - Water tank equipped with boiler, small pump, valves, ultrasound level meter, overload detector and thermocouple.

within deterministic delay bounds. In this work, attention was focused on the *Communication Administrator* (CA) which is responsible for communication between server and client and, therefore, it encapsulates the particular protocols in use.

The use of a standard TCP/IP protocol could not guarantee delay bounds. It ensures data delivery by using packet re-transmission when the loss of packets occurs in a loaded network such as the Internet, and in this way became a heavy and non-deterministic protocol.

By using the User Datagram Protocol (UDP), on the other hand, transmission is lightweight but data delivery is not guaranteed, and, therefore, is not suitable for control applications when used alone.

Implementation of the CA is based on the General QoS (GQoS) [13, 14] interface in order to take advantage of the RSVP protocol. In the laboratory tests, the RSVP implementation from Microsoft was used. The use of UDP sockets with a QoS set for both data and command transmission ensures reservation of the necessary bandwidth and packet priority in the client queue, on the server and on the routers along the server to client path. As it has above been mentioned, the RSVP guarantees quality of service only in one transmission direction, and in order to ensure delay bounds in both directions two distinct reservations are made for server data transmission and client command transmission. The use of the UDP when the bandwidth is reserved makes packet delivery from sender to receiver really lightweight.

The implemented software architecture is delay-deterministic in each single part: (i) the delay bounds on the measurement procedure are equal to the sum of the execution time of each step in the measurement loop, and (ii) the delay bounds on data transmission via the Internet are equal to the delay in physical transmission of packets from server to client and the bounded delays due to scheduling of the packets on each router along the server to client path.

Different experiments were carried out with the prototype in the laboratory in order to verify the validity of the proposed architecture. In these experiments, the bandwidth between the routers was fixed at 64kbps. The resources which need to be reserved by the measurement application depend on both the acquisition rate and bit number of the Analog-to-Digital Converter (ADC) setup on the server side.

Assuming the rate selected for level and temperature acquisition was limited to 100 sample/s, and 16 bit ADC, the minimum bandwidth for data transmission was limited to (2x100 sample/s)x16=3.2kbps.

4. QoS ANALISIS OF THE RSVP-BASED SYSTEM

This Section describes a methodology for QoS measurement on IP-networks aimed to comparing the performance of an RSVP-based system with one without RSVP, and the results are discussed. The proposed methodology is not intended to simulate Internet behaviour but rather to obtain valid measurement results which will allow a distinction to be made between a RSVP communication and a traditional best-effort based one. The set of metrics established for the measurement of the QoS of the IP-networks were defined in [15, 16]. In particular, packet loss, end–to–end packet delay and delay jitter are three factors which give a clear picture of the QoS of the particular network, and are vital when the performance of real-time applications over the Internet in the industrial sector is addressed. These metrics are briefly described in the following:

1. *Packet loss*. Network devices, such as switches and routers, sometimes have to hold data packets in buffered queues when a link becomes congested. If the link remains congested for too long, the buffered queues will overflow and data will be los t;
2. *End–to–end delay*. The time taken by data to travel from their sources to their destinations is known as end–to–end delay. The delay can be caused by packet processing and congestion;
3. *Delay jitter*. This is the delay variation caused by variation in queue length, and variation in the processing time needed to reorder those packets which arrived out of order because they have travelled different paths.

The attention was focused on the measurement of these parameters. In the experimental system two LANs are connected by means of two Cisco 1750 routers. The throughput of the inter-Cisco connection was set to 64kbps. Both routers are RSVP enabled and a 20kbps bandwidth reservation configured. A datagram RSVP socket is set up between the PC1(WIN 98) on LAN1 and the PC2(Win 98) on LAN2 together the request for a load service. In addition, an ordinary datagram socket is opened between both PCs.

4.1 General considerations

The experimental network has numerous limitations which distinguish it from the real Internet. The obvious one being due to the reduced number of routers used. Neither simulation of the IP-route dynamism, nor investigation of the adaptive RSVP soft-state configuration due to route changes can be effected. The experimental system does, however, offer a good basis for comparing both RSVP and RSVP-less packet transmission. Although the packets from both sockets follow the same Internet path, a reliable comparison of packet loss and packet delay behaviour between these two transmission modes is still to be made.

Another problem related to end–to–end packet delay and delay jitter measurement is the synchronisation of both sender and receiver [17]. Indeed, clock synchronisation proves essential for an exact evaluation of these metrics. Different approaches relying on the GPS, telephone network and the NTP protocol, were proposed in [18]. In the simulated network, however, no synchronisation was provided; rather, a new metric, aimed at characterising the end–to–end delay variation in the investigated cases, was introduced. This metric allows the comparison of the delay behaviour of packet transmission in the cases under study and it is a QoS indicator for the router in terms of how the delay may vary due to buffering, QoS treatment (admission control, classification and scheduling), and congestion. Moreover, it eliminates the problem of clock synchronisation. Indeed, if x (on the PC1) be the sending instance and y (on the PC2) be the receiving one, then the value of y-x will be used to estimate the end–to–end delay variation.

The type of traffic generation is not considered in this study, underlining the fact that the main objective is not to simulate real Internet behaviour, but to compare the performance of RSVP and RSVP-less packet transmission. Either simple linear packet traffic or the Poisson process, as recommended by IP Performance Metrics (IPPM) group [16, 18], can be generated.

4.2 Packet loss measurement

The first QoS parameter measured was packet loss. Numbered UDP packets were sent through both sockets and the number of packets which arrived is checked by the receiver. If a packet with number k is expected and three packets arrive with the number j>k, the packet k is marked as deferred or lost. If it doesn't arrive until the end of the measurement period, it is considered to be definitively lost. The size and sending frequency of the packets and the experimental period can be varied in order to study different network behaviors. Basically, the inter-router limited throughput leads to continuous buffering and then to buffer overflow and packet dropping (loss).

Different measurements, setting the parameters for the packets in transit on both the RSVP and RSVP-less sockets, were carried out, and the results are given in Table 1.

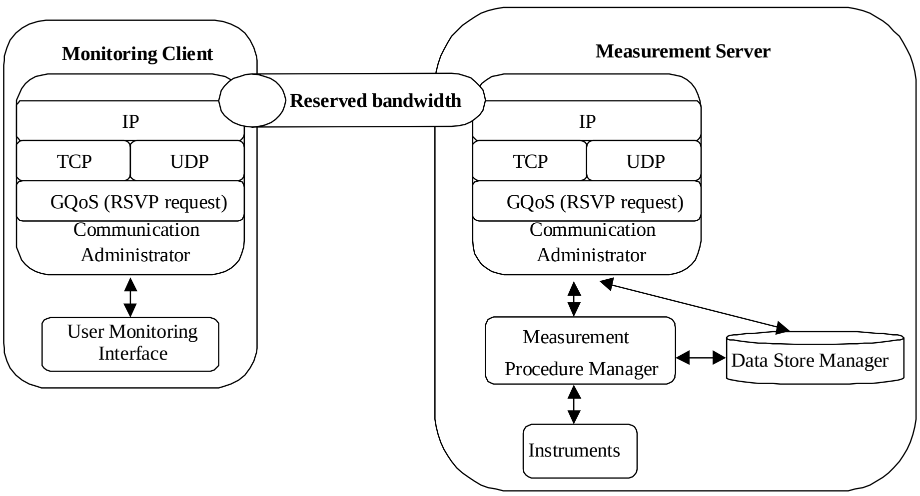


Fig. 3 - The software architecture.

To summarise:

- Case1: the total of RSVP and RSVP-less traffic is not greater than the network throughput: no loss is detected.
- Case2: the total of RSVP and RSVP-less traffic is greater than the total network throughput: (i) the RSVP traffic is lower than the total amount of resources that can be reserved on the routers (20kbps): no loss is detected for the RSVP traffic, whereas the RSVP-less traffic looses packets once the router's buffers are overflowed; (ii) the RSVP traffic is greater than the total amount of resources that could be reserved on the routers: loss is detected for both RSVP traffic (even if limited) and RSVP-less traffic once the router's buffers are overflowed. Deterioration of the QoS is noticed for the RSVP traffic.

Table1 - Packet loss measurement result (total bandwidth =64Kb, reservation up to 20Kb).

Traffic		Socket	Observation interval [s]	Packet size [bytes]	Packet rate [packets/s]	Packet loss [packets]
Total	RSVP					
<64kbps	<20kbps	RSVP	200	1000	1	0
		RSVP-less	200	1000	7	0
	<20kbps	RSVP	200	100	2,5	0
		RSVP-less	200	100	1	0
>64kbps	<20kbps	RSVP	600	1000	2,5	0
		RSVP-less	600	1000	10	2183
	<20kbps	RSVP	60	250	2,5	0
		RSVP-less	60	250	20	705
	>20kbps	RSVP	200	1000	5	115
		RSVP-less	200	1000	10	1023

4.3 Delay measurement

Measurements of the delay variation were carried out by sending numbered UDP packets, transmission time being recovered. The transmission time x was noted just before the packet was sent. The arrival time of the packet y is also recorded. Time detection is delegated to the system clock, its resolution being approximately equal to 50ms. This parameter has to be considered when measurements are discussed. For each packet received, *delta* =y-x is calculated and taken as the indicator of delay variation.

Measurement results are shown in Fig.4 where *delta* is reported for each packet in the order of the packet's arrival. To summarise:

- Case1: the total of RSVP and RSVP-less traffic is lower than the total network throughput: the RSVP traffic *delta* and RSVP-less traffic *delta* comprises a range of 120ms (taking into consideration the 50ms of clock detection resolution).
- Case2: the total of RSVP and RSVP-less traffic is greater than the total network throughput: (i) the RSVP traffic is lower than the total amount of resources that can be reserved on the routers: for this traffic, *delta* comprises a range of 120ms, with a uniform distribution of the values. For the RSVP-less traffic, *delta* initially increases linearly, and subsequently flattens due to the loss of packet "stability" after the router's buffers overflow. It comprises a range of 12s (the 50ms clock detection resolution is insignificant); (ii) the RSVP traffic is greater than the total amount of resources that can be reserved on the routers: deterioration of the QoS is noticed in this traffic; indeed, *delta* initially increases linearly, and subsequently flattens due to the loss of packet "stability" after the router's buffers. This comprises a range of 8s. For the RSVP-less traffic, *delta* increases linearly, and subsequently decreases due to packet loss of the RSVP traffic and finally, flattens due to the loss of packet "stability" after the router's buffers overflow. It comprises a range of 12s.

The first experimental results provide good indications of packet loss and delay behaviour. They clearly demonstrate the advantage and the reliability of the RSVP-based data transmission versus the traditional best-effort one.

Even if the evaluation is only approximate, the results are satisfactory for real–time industrial applications over the Internet, being limited to a precision of some tens of ms. For these kinds of applications, the QoS measurements may be considered both reliable and valid.

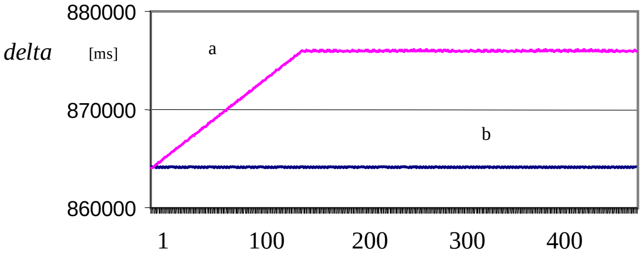
5. SECURITY CONSIDERATIONS ABOUT THE RSVP-BASED DISTRIBUTED MEASUREMENT SYSTEM

Communications over Internet are intrinsically not secure. The security problem can be study in two directions: (i) security of transmitted data and of the resources made available through Internet, and (ii) security and integrity of the overall distributed system.

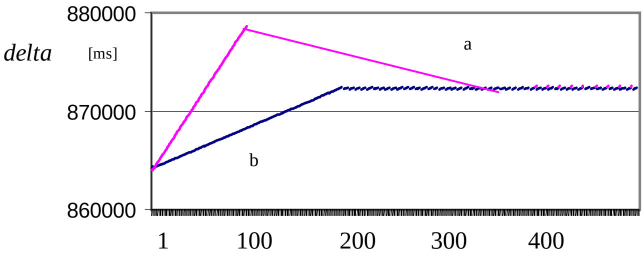
The first aspect treats the possibility (i) of hacker's attack in the distributed measurement system, with subsequent resources modification or damage, and (ii) of network sniffering in order to access the confidential transmitted data, and manipulate them maliciously. The protection against these problems is the digital certificate authentication (conforming to the ITU recommendation X.509 [19]) when the measurement resources are accessed and the encryption when the data are transmitted (public/private key RSA algorithm [20]).

The second aspect concerns with the possibility of Internet node crash. The protection against this problem is given us in part from the RSVP protocol. In fact, RSVP mechanism requires periodic routers soft-state refresh along the reservation path, and this is accomplished by sending periodically PATH and RECV messages along this path. Each failure in recourses availability will be reported by RSVP sending back PATH-ERR and RECV-ERR messages (in response respectively to the PATH and RECV messages). The CA will detect such messages and will forward them to the *Measurement Procedure Manager* (MPM). The subsequent activity depends on the adopted security policy. When critical industrial systems are controlled the MPM has to put the system in one secure state and stop the measurement procedure until the connection with the remote controller is established again. Once the connection has been activated the remote controller is informed about the current status and can continue/restart the measurement procedure.

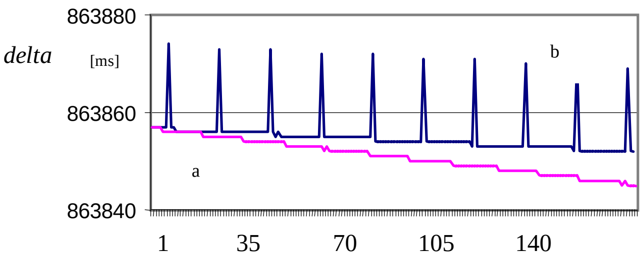
application multi-users to take advantage of the multicasting protocols.



Observation period=200s; Rate RSVP traffic=2,5packet/s; Rate RSVP-less traffic=10packet/s; Packet size=1000 bytes



Observation period=200s; Rate RSVP traffic=5packet/s; Rate RSVP-less traffic=10packet/s; Packet size=1000 bytes



Observation period=200s; Rate RSVP traffic=2,5packet/s; Rate RSVP-less traffic=1packet/s; Packet size=10 0 bytes

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Fig.4 *delta* reported for each packet, in the order of the packet arrival: (a) RSVP- less traffic, and (b) RSVP-traffic.

6. CONCLUSIONS

The performance of RSVP based distributed measurement and control systems over the Internet are considered.

The methodology for Quality of Service measurement on IP-network and the aspects concerning the security of distributed measurement systems are examined.

Experiments carried out at the Laboratory for Signal Processing and Measurement Information (LESIM) [21] at the University of Sannio, Benevento (Italy), using an emulated Internet with traffic load, demonstrate the validity of the RSVP-based architecture.

Further evolution of remote real–time monitoring and control over the Internet could take place by enabling real-time application multi-users to take advantage of the multicasting protocols.

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