

## THE "R.I.O." : AN INTERNATIONAL RESEARCH NETWORK IN DEVELOPING COUNTRIES.

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### Abstract

Research networks enable scientists working in distant laboratories to carry out common programs and to exchange data processing tools. As a consequence to them, the powerful computing resources of important laboratories are available for less well-off research teams. The development of these networks during the past years has been so great that most public or private research institutions in Europe and North America are now linked up to them. By helping to establish regular contacts between researchers in different towns, countries and continents contributes to strengthen the links existing within the international scientific community.

For developing countries, geographically far away from technological centres, the computer networks are a very efficient aid to technology transfer. They allow the local scientific communities to establish permanent links with top laboratories in the northern countries.

The relatively vulnerable telecommunication infrastructures of those countries (*jammed* telephone lines, scarcity of places linked through a public X 25 network) is a factor that contributes to the isolation of scientific teams and which makes computer networks equally useful and difficult to implement.

ORSTOM has involved itself in the setting up of a network which presently interlinks laboratories in ten countries. This network, member of Fnet and EUnet, communicates with the large international networks of research and university.

The "R.I.O." uses public communication networks (RTC or X25) and makes do with relatively noisy lines. Its communication nodes are cheap Unix machines. Acting as gateways to local networks of micro-computers, they give non-computer people access to the network services from their P.C.

### Keywords

Inter-continental network, interconnection of local networks of micro-computers, UNIX, research network, developing countries, research for cooperation

## **1. THE RESEARCH NETWORKS**

The research networks were born, some twenty years ago, out of the need to share huge and expensive computers. They have experienced a complete turnaround, during the last decade, with the appearance of mini and microcomputers. Nowadays, the need is no longer for sharing powerful resources but for offering new means of communication on the scale of the international scientific community.

The speeds that previously ranged from 300 to 9600 bps now reach 1 000 000 bps. The number of national and international networks increased in all developed countries and they now interconnect thousands of computers. EARN, BITNET, NETNORTH, GULFNET represent a set of 3158 nodes distributed in forty-two countries [EARN90] while EUNET interlinks over 1800 institutions in Europe and UUnet 15 000 in the world [DON90,EUUG].

The density of the networks that link researchers and engineers of all countries via the computers, is not just a valuable tool ; it creates within the international scientific community a sense of fellowship and a will to cooperate.

On the other hand, developing countries reap only minor benefits from this multiplication of the networks. This evidently results from the low technological level of the countries but also from the conviction shared by many of those in charge, that computer networks rest upon a heavy technology and involve high telecommunication costs. The experience that we are going to describe shows that, on the contrary, it is possible to develop a computer network on a large geographic scale by linking groups of cheap work stations.

We have noted that, very often, the most enthusiastic users were found in places extremely distant from the high technology centres. Indeed, since as they reduce the drawbacks of time and distance, the computer networks are potentially more beneficial for outlying laboratories.

## **2. INTEREST OF RESEARCH NETWORKS FOR DEVELOPING COUNTRIES**

### **2.1. TECHNOLOGY TRANSFER**

Owing to the low price of personal computers, data processing has been able to spread in all countries, but this doesn't mean that its technology is mastered everywhere.

The laboratories of "research - development" are the very first users of the networks. Software-banks of public domain have been constituted by certain scientific organizations in order to allow a wide diffusion of new tools and techniques. The free diffusion of such softwares and the possibility of getting

advice from their developers play an important part in the spreading of knowledge in the field of data processing.

The access that the scientific and technical community is given to these tools is an asset for the technological control of data processing.

## **2.2. NORTH-SOUTH RESEARCH AND COOPERATION**

Developing countries are installing research structures, particularly in the fields of health and agronomy. In most cases they collaborate with international organization and laboratories in Northern countries. These collaborations, indispensable for real research potentialities to appear, create an increasing need for communication. A computer network provides a relevant answer to this need. It allows the interlocutors to maintain a frequent, informal and free dialogue (which is not the case with the telephone) and it puts the teams in touch on a level of technological equality.

It becomes possible for the members of a research team dispersed throughout the world to carry out a common project, as the network allows them to advise each other on the preparation of an experiment, the writing of a paper or report, to exchange bibliographic notes or to have some heavy data processing job done elsewhere.

## **2.3. THE SCIENTIFIC COMMUNITY IN SOUTHERN COUNTRIES**

The methods and subjects of research in the developing countries are not a mere transfer of the research carried out in the industrial countries. Their targets are closer to meeting the population's vital needs (food, health, education). The results have to be adapted to the social structures, the customs and the technology growth rate of the country.

In this case too, cooperation with other "units" working under similar conditions is quite desirable. It has been noted that many problems in agriculture, fishing or health are common to several continents but also that this is true in some fields of human sciences as "urbanism", economy, etc.

At present, the metropolis is far too often an obligatory thoroughfare for communication between researchers in developing countries. We are certain that computer networks - on the condition that cheap but reliable techniques are set up - can contribute in creating horizontal links within the scientific community of the Southern countries.

### **3. DIFFICULTIES ARISING FROM THE SETTING UP OF NETWORKS IN THE SOUTH COUNTRIES**

#### **3.1. TELECOMMUNICATION INFRASTRUCTURE**

Many countries in Africa and South America are equipped with public X 25<sup>1</sup> networks. The quality of these recently installed networks is good and their fees reasonable. Such an effort on equipment is an asset for research networking.

We must not however forget the countries that could not bear this effort; they have to use dial-up lines. Unfortunately their quality is often rather bad (frequent cuts, noise) and their speeds low (generally 1200 to 2400 bps). Finally, though connection via satellite is always technically possible, this technology is expensive and consequently unsuitable for research establishments with a small budget.

#### **3.2. TECHNICAL ENVIRONMENT**

Several kinds of difficulties :

- staff : research establishments have few technicians able to manage computers and networks.
- the suppliers' technical maintenance is seldom sufficient to provide the help needed to install networks.
- computer maintenance is expensive. It is not provided everywhere for the type of computers we are interested in.
- the suppliers' proposals, in the matter of networking, are generally based on very costly equipment and leased lines (X 25 lines in the best case).

#### **3.3. ADMINISTRATIVE RESTRAINTS**

People in charge of the budget are concerned with the risk of an uncontrollable increase in telecommunication expenses while the management seems to fear written information circulating too easily between their establishment and the outside world.

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<sup>1</sup>X25 is ISO reference for Paket data transmission network as Transpac [PUJ90]

## 4. HISTORY OF THE R.I.O<sup>2</sup>.

### 4.1. THE DIRECTING SCHEME

This network is one of the results of the "directing scheme of scientific data processing" developed since 1986. This diagram defines the following orientations :

- decentralization of data processing equipments;
- three levels organization of data processing : individual level (P.C.), department level (workstations) and supercomputer level (exterior);
- choice of homogeneous equipments at department level. The range of equipment must cater for the wants of ORSTOM's different scientific applications : scientific computing and numeric models ; remote sensing and image processing ; databases and geographic information systems; artificial intelligence;
- respect of the following compatibility standards :
  - UNIX system,
  - ethernet local networks : TCP/IP and NFS,
  - development libraries : GKS, X-Windows;
- definition of a local architecture integrating the different levels on each site;
- Interconnection of sites within an international network (the R.I.O.);

### 4.2. THE STAGES IN THE INSTALLATION OF THE R.I.O.

1986 - 1987 : Equipping of larger centres : Bondy, Montpellier, Noumea ; installation of Transpac lines in the first two.

1988 - 1989 : Development of the network : equipping of Paris (connection with administrative data processing), Dakar, Cayenne, Ouagadougou, Yaounde ; installation of UUCP/F connections, connection with Fnet.

1990 - 1991 : generalization stage : equipping of Bamako, Lome, Seychelles, Abidjan, Niamey, Pointe à Pitre, Papeete, Quito (ecuador), Fidji, Vanuatu...

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<sup>2</sup>Réseau informatique de l'ORSTOM et Réseau Inter-tropical d'Ordinateurs

### 4.3. DIFFICULTIES

- The first difficulty was to arouse the interest of future users; we had a very determined policy. Researchers - now convinced and enthusiastic - did not have a clear idea of the advantages of telecommunication.
- The second difficulty was to obtain telecom lines : we had to manage with what was available : to use one of the switch-board lines, to share a telefax line, etc. In some towns, to get a new line is a long and exacting task requiring a lot of diplomacy.
- Another problem is the remoteness of suppliers. When a spare part is missing, when software is damaged by a manipulation error, it is a disaster.

The poor quality of the lines was never a hindrance. Protocols we use, accept noisy lines (when the *login* procedure is over, UUCP makes do in rather difficult conditions).

## 5. TECHNICAL PRESENTATION OF THE R.I.O.

### 5.1. A POLYVALENT HARDWARE : UNIX WORKSTATIONS

The Unix system, specially in BSD release, include in the standard package, a very usefull set of telecommunication software: UUCP (Unix to Unix CoPy) that works on a single dial-up lines; TCP/IP for high speed networks, Mail (or Mailx) for electronique mail. But Sun workstations offers many more usefull tools:

- each workstation has two RS423 interfaces (synchronous and asynchronous)
- The Sunlink software is able to emulate a PAD<sup>3</sup> function (up to 19200 bps and 16 virtual connexions) without any additional hardware.
- The same station can emulate an IP<sup>4</sup> router on X25 with the same Sunlink
- Sun provides uucico-f (consulting product) that allow to use UUCP on X25 lines and specially on the PAD function emulated by Sunlink.

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<sup>3</sup>Packet assembly disassembly: entry point into a X25 network

<sup>4</sup>Internet Protocol

## 5.2. COMMUNICATION TECHNIQUES THAT HAVE BEEN IMPLEMENTED.

Our aim was to make the best use of the available telecommunication means according to these objectives :

- reliability of the system
- smallest possible working costs so as to make it available to everyone
- guaranteed delivery time. Electronic mail must be roughly as fast as telefax, for instance.

We use the X25 network when it exists. But it is sometimes difficult or too expensive to get a direct connection to a concentrator ; we then use the dial-up access to a public PAD connection.

The five solutions we are going to describe range from the most "comfortable" to the "lightest" one. They rely on UNIX system protocols : UUCP and TCP-IP.

### **Solution 1 : X25 on direct line, encapsuled IP protocol**

Hardware : SUN 3 or SUN 4 under SUNOS™ 4.x

Commercial softwares : SUNLINK™

A RS423 port of the SUN is directly connected to the synchronous modem. X25 protocol management is ensured by Sunlink. Connection to the other sites of R.I.O. uses IP with "X25-Manager<sup>5</sup>" or "Tunnel<sup>6</sup>".

IP connection needs a X25 line with a rate equal or superior to 9600 bps [DIR90]. But it is the most "comfortable" solution. Computers connected this way work exactly as if they were on the same local TCP-IP network (except for the speed). It is therefore possible to use the commands of TCP-IP networks : telnet<sup>7</sup>, FTP<sup>8</sup>, etc. Messages are immediately forwarded to the destination by SMTP<sup>9</sup>.

This is a relatively expensive solution, it entails fixed costs (X 25 rate) and higher working costs: creation of numerous virtual circuits, excess of characters generated by the encapsulation of IP packets over X25 It is used between the R.I.O. sites of Montpellier, Bondy and Paris as well as in R.I.O.-Fnet connection.

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<sup>5</sup>include in the Sunlink Package

<sup>6</sup>public domain software developed by Julian Onions, Nottingham University

<sup>7</sup>TERminal Local NETwork : virtual terminal function

<sup>8</sup>File Transfert Protocole

<sup>9</sup>Simple Mail Transfert Protocole (TCP package)

**Solution 2 : X25 on direct line, UUCP/F protocol**

Hardware : SUN 3 or SUN 4 under SUNOS 4.0.x

Commercial softwares : SUNLINK™

As previously, a RS423 port of the SUN is directly connected to the synchronous modem. X 25 protocol management is ensured by Sunlink.

UUCP/F protocol is a UUCP version for secure lines [DEV88]. It is adapted to X 25 transmission whatever the speed. As all UUCP connections, it is a store-and-forward link ; data to be transmitted is stocked on the site then forwarded. Mail is sent either at each request or at fixed times, all requests being gathered in a single [ORE86].

Transmission costs are lower with this solution, the occupation time of the virtual circuit is reduced to a minimum and UUCP/F produces very few extra characters (only one checksum by file). It is used in Dakar and Niamey.

**Solution 3 : using X 25 network through public PAD**

The problem is to connect to a public PAD through a dial-up line or a V22 type asynchronous direct link.

Hardware : SUN 3 or SUN 4 under SUNOS 4.0.x

An RS423 port of the SUN is connected to an asynchronous modem. Connections to other sites of the R.I.O. are established under UUCP/F protocol if the line to the PAD is good, under G protocol if not.

This solution gives good results without entailing investments as we manage with an access point to a public PAD (generally cheap).

This solution is used at Lomé, Nouméa, Lannion, Abidjan, La Réunion and Cayenne.

**Solution 4 : Dial-up telephone lines**

Hardware : any UNIX machine.

An asynchronous port of the computer is connected to the asynchronous modem. The connection to other R.I.O. sites is made under UUCP protocol. This is the classical UUCP solution [ORE86].

The cost of this solution depends on the quality of the line. Connections fail when extra characters are received in the connecting phase. It is then necessary to run UUCP again. Once the UUCP connection is made, the

repetition of packets lengthens transmission times. There are three ways to obtain a notable improvement :

- by increasing the rate (if the quality of the line is good enough)
- by using a correcting and compressing modem (NMP5 protocol). In this case, it is necessary to use UUCP/F, which is the only protocol able to handle the rate control (Xon-Xoff) . This solution is being studied on the Seychelles connection.
- by using a multi-frequence modem (type Telebit TrailBlazer Plus™) but it is not yet patented in France.

### **Solution 5 : UUCP under DOS**

This interesting variant of solution 4 is presently being studied. It simply uses a DOS machine that emulates UUCP protocol; with a distant site this machine behaves like a UNIX machine.

Two softwares permit the emulation of UUCP under MD-DOS : UULINK and UUPC<sup>10</sup>. This solution is being studied in Fidji and Ecuador.

### **5.3. GENERAL ORGANISATION OF THE NETWORK**

The R.I.O. is built radially around the backbone installed in Montpellier. In every linked country, a distant site is directly connected to the central site. This organisation provides a high reliability and the lowest possible telecommunication costs.

Data routing (files, messages) is made in the following way :

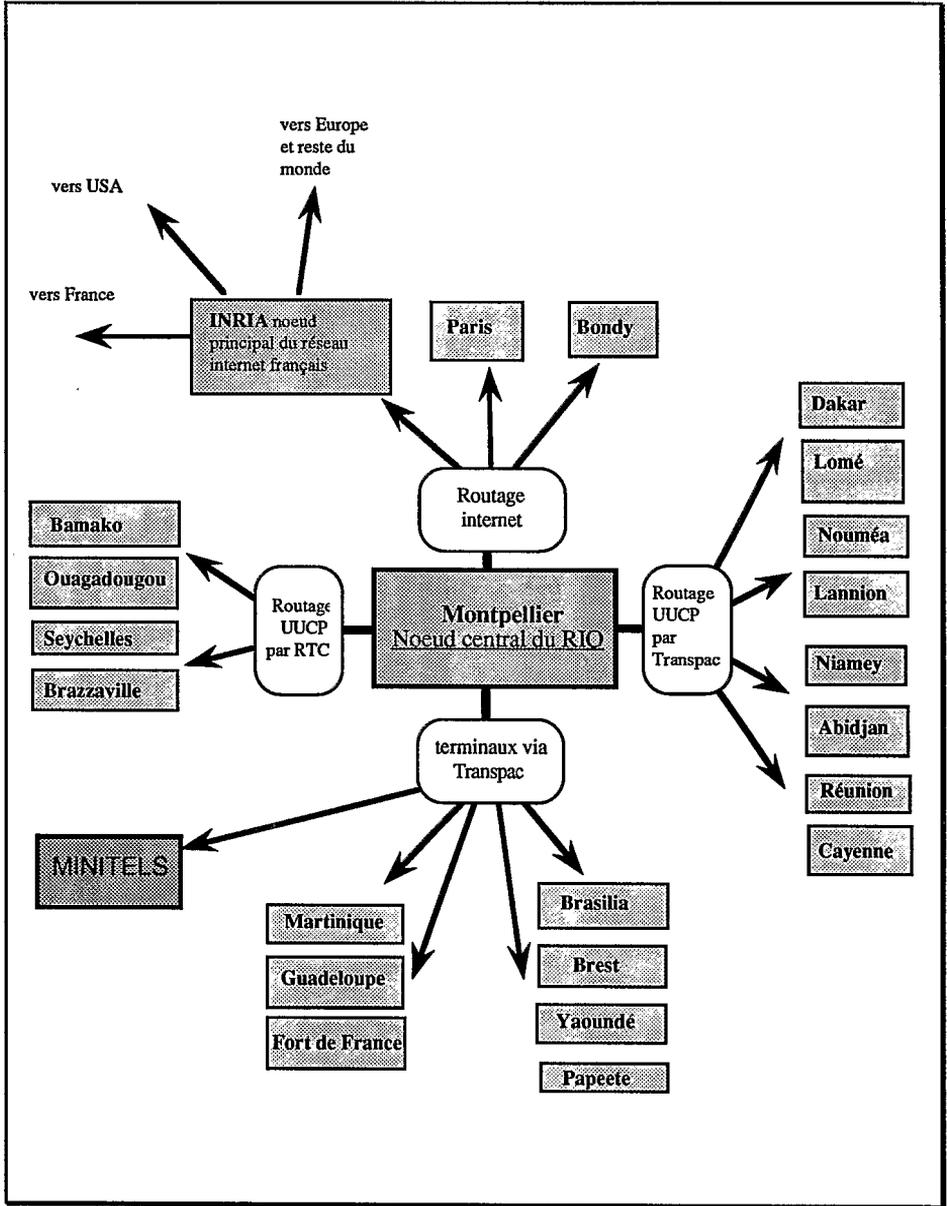
The secondary node stores data addressed to local users and transmits to Montpellier data addressed to other machines. Montpellier routes the mail to the secondary nodes of the R.I.O. and transmits to Fnet (INRIA Rocquencourt) the messages for other establishments.

For some installations, access to the R.I.O. is possible by direct connection to the backbone via Transpac.

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<sup>10</sup>Public domain software

### Général map of network routing



## nodes already in use

town and domain adresse	hardware	telecom link	speed	protocoles	number of connexions
Montpellier <i>orstom.orstom.fr</i>	Sun 3/80	Transpac: 8 CV RTC: 2 lines: 1: 1200 bps 2: 2400 NMP5	19200 bps	IP/X25 UUCP/F UUCP/G	permanent link to INRIA-Rocquencourt
Bondy <i>bondy.orstom.fr</i>	Sun 3/260	Transpac 8 CV	9600 bps	IP/X25 UUCP/F	permanent link
Paris <i>paris.orstom.fr</i>	Sun 3/50	Transpac 4 CV	9600 bps	IP/X25 UUCP/F	permanent link
Nouméa <i>nouméa.orstom.fr</i>	Sun 3/260	Transpac by RTC	1200 bps	UUCP/F	twice a day
Seychelles <i>seychel.orstom.fr</i>	Toshiba 5200 sous 386 IX	RTC	1200 bps	UUCP/G	once or twice a day
Bamako <i>bamako.orstom.fr</i>	Léanord sous 386IX	RTC	1200 bps	UUCP/G	once a day
Ouagadougou <i>ouaga.orstom.fr</i>	G5 sous 386IX	RTC	1200 bps	UUCP/G	once a day
Dakar (hann) <i>dakar.orstom.fr</i>	Sun 3/60	Senpac 2 CV	2400 bps	UUCP/F	3 times a day
Dakar ISRA <i>isra.orstom.fr</i>	Sun 3/260	Senpac 2 CV	2400 bps	UUCP/F	twice a day
Lomé <i>lome.orstom.fr</i>	Sun 4/65C	Togopac 1s V22	1200 bps	UUCP/F	once a day
Cayenne <i>Cayenne.orstom.fr</i>	Sun 4/110	Transpac by RTC	1200 bps	UUCP/F	twice a day
Niamey <i>niamey.orstom.fr</i>	Sun 4/65C	Nigerpac by RTC	1200 bps	UUCP/F	twice a day

## plan for 1991

town	hardware	telecom link	speed	protocoles
Abidjan	BM60-IX	Transpac by RTC	1200 bps	UUCP
St Denis de la Réunion	Sun 3	Transpac par RTC	1200 bps	UUCP/F
Lannion	Sun 4/65C	Transpac par RTC	2400 bps	UUCP/F
Vanuatu		RTC vers Nouméa	2400 bps	
Papeete		Transpac par RTC	1200 bps	UUCP/F

## 5.4. INTEGRATION OF LOCAL NETWORKS IN THE GENERAL SCHEME

### *UNIX™ machine as multi-functions server.*

There is an increasing demand for local networks from personal computer users. These micro-computer networks allow better team working, more rational use of costly peripherals (laser printers, plotters, etc.) and the running of data sharing applications. But the installation of a local micro-computer network is relatively expensive and requires good knowledge to be correctly administered.

The solution chosen for the R.I.O. involves using the UNIX system that ensures the telecommunication with the remaining sites as local network server[DOU87]. This network then has additional facilities at its disposal for a smaller marginal cost :

- data communication (messages, files) from micro to micro between the different sites,
- access from the micro to the UNIX machine resources (peripherals, softwares)
- security of access guaranteed by the UNIX system.

Network services are ensured by Ethernet, TCP-IP protocols (distant terminal and files transfer functions) and PCNFS™ protocol (files server and printer sharing under DOS). An UNIX server is recognized by the Macintoshes as an Apple-Share server and as a NetBIOS™ server by the PC under MS-DOS™.

## 5.5 THE SERVICES OF THE R.I.O.

### 5.5.1. Electronic mail

Mail is the basic service of all distant networks. It allows a completely confidential transmission of texts ranging from a few lines to more than 50 pages.

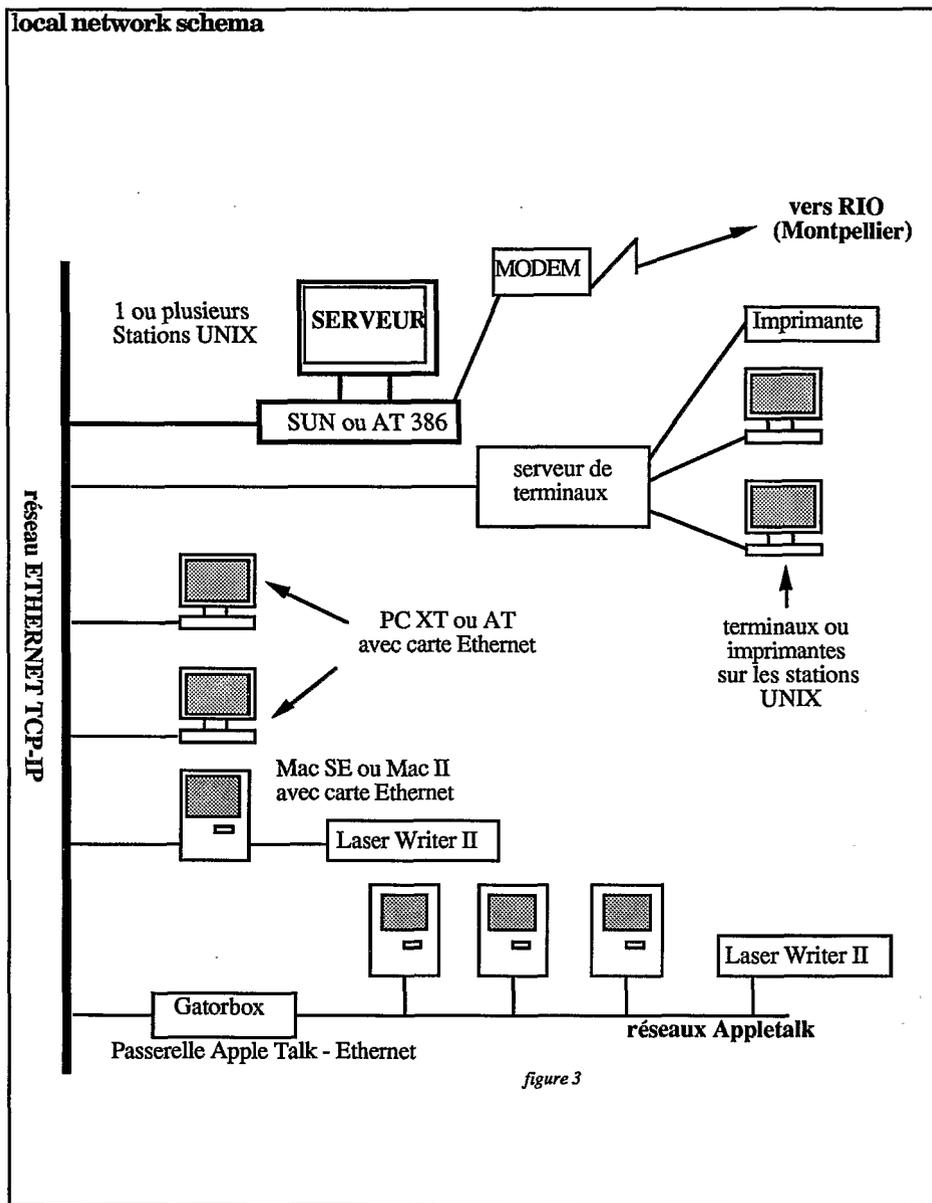
The text is typed on a network machine or Minitel. It can be written with a word processing software. The recipient receives the message in an electronic mailbox at his usual machine (micro or mini-computer or Minitel). After reading, the message may be kept in a file and processed again.

Through Fnet<sup>11</sup> connection, R.I.O. mail allows its users to correspond with all the users of international networks such as EUnet, EARN, Bitnet, European

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<sup>11</sup>French network of AFUU (Association française des utilisateurs d'UNIX) member of EuOpen (ex European Unix User Group).

and American Internet, UUnet, Usenet, etc. It connects hundreds of thousands of people in research, higher education and top industries.



Every user has a mailbox with an electronic address. This is the only one on the international networks. The sender's message is identified by a password that guarantee its authenticity and confidentiality. A message can be sent to more than one recipient and automatically re-forwarded.

### *Accents*

The standard for message format in the R.I.O. mail system is RFC822. This system only includes ASCII characters (7 bits). For French speaking users, the absence of diacritical accents is a nuisance and may make the text difficult to read. This is the reason why at ORSTOM we developed two softwares : PCMESSOR and NFSMESSOR that encode special characters before the transfer. The characters with accents are encoded into pure ASCII (7 bits) which make them compatible with other standards but their interpretation ((),...) is modified in accordance with NRC standard. This implementation is compatible with the bi-standard Minitel in mode tele-processing, french terminal.

### **5.5.2. Documents transmission**

The mail service is limited to sending texts. By "documents transmission", we mean : sending reports processed with a word processing software and containing different styles, fonts, formats and justification commands.

The principle is as follows : the document is encoded into an intermediate format and integrated into the message ; on arrival, it is re-converted into its original form. This technique allows the transmission of 50 pages documents, with addition of graphs and drawings made with a standard word processing software (on Macintosh or IBM compatible PC). Documents may be recuperated and modified by the recipient who has got the same or any other compatible software.

### **5.5.3. Files transmission**

It is a question of transmitting sets of scientific (or management) data intended to "feed" a processing software. These data seldom appear in the shape of a text, that is why text transmission and files transmission are two completely different problems. Besides, files transmission requires absolute reliability, since the smallest error can alter all subsequent processings

Several files transmission methods are implemented on the R.I.O. : FTP, reserved to the sites with a high or medium speed connection ; UUCP - direct transfer or "by message" available to all servers and finally KERMIT that allows files transmission from a dial-up linked micro-computer.

#### 5.5.4. Electronic forum

Electronic forum is a tool for scientific debates. It is the mail equivalent of a telephone forum. Contributions are made through messages automatically delivered to every participant.

A forum consists of a group of R.I.O. users, each of whom has a mailbox. Their addresses are registered in a distribution list. The forum is given the name of this list.

##### *The forum animator*

Each forum is under the responsibility of an animator. He asks for the opening of the forum and is able to answer any question on the subject, the members and the nature of expected contributions.

#### 5.5. CONSULTATION OF DATABASES

##### *interactive mode*

Workstations at sites with an access to Transpac or any of its equivalents (Tompac, Nigerpac, Senpac, etc.) may consult databases in interactive mode. ORSTOM administrates a documentary base, HORIZON, as well as administrative databases on computers belonging to the R.I.O.

##### *store and forward mode , by message to an "info-server"*

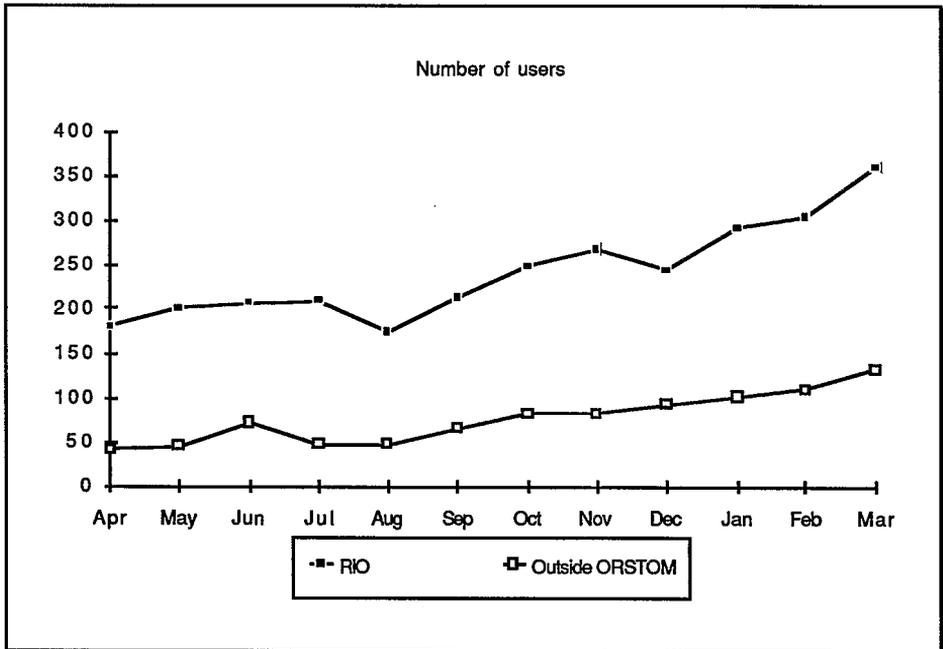
An info-server is a program that automatically answers a message sent to it. The message includes a request which is interpreted and the result is sent back to the sender. Info-servers may be used from any access to the R.I.O. (including the external ones).

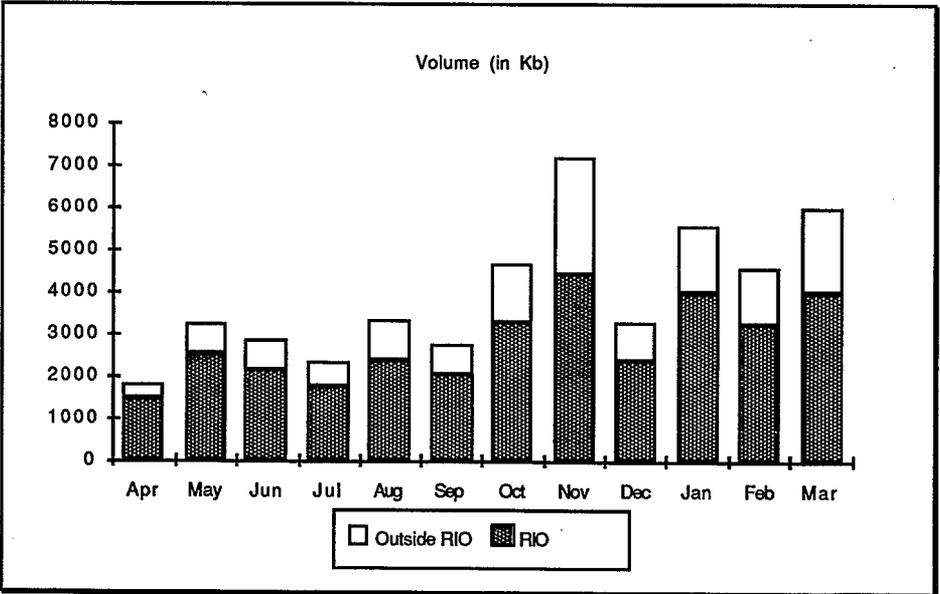
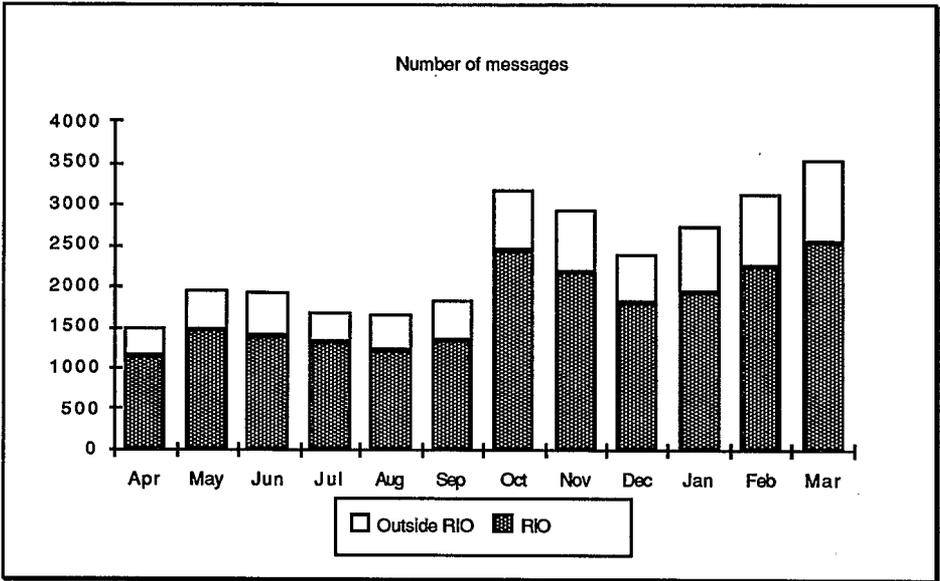
## 6. RESEARCHERS AS USERS OF THE RIO

An account can be opened only at the user's request. So far, about 500 people (out of 1800 ORSTOM employees, including all categories) have been registered and 250 are using it regularly. Users are geographically distributed as follows : About 500 accounts distributed in many implantations :

ABIDJAN (Côte d'Ivoire)	27	LOME (Togo)	15
BAMAKO (Mali)	20	MARTINIQUE (Antilles fr.)	1
BONDY (France)	54	MONTPELLIER (France)	60
BRASILIA (Brésil)	2	NIAMEY (Niger)	15
BREST (France)	13	NOUMEA (Nouvelle Calédonie - Fr)	25
BRUXELLES (Belgique)	1	OUAGADOUGOU (Burkina-Faso)	10
CAYENNE (Guyane fr.)	11	PAPEETE (Tahiti - Fr)	3
DAKAR (Sénégal)	55	PARIS-SIEGE (France)	110
GUADELOUPE (Antilles fr.)	2	VICTORIA (Seychelles)	3
LA REUNION (France-TOM)	6	VILLEFRANCHE (France)	7
LANNION (France)	5	YAOUNDE (Cameroun)	5
		Divers France	30

Every month, some 3000 messages are exchanged, 10 % of which to mailboxes out of ORSTOM. The volume increases by more than 50 % every year.





## 7. BUDGET

### 7.1. EQUIPMENT

The investment made for the R.I.O. is a part of the budget for data processing equipment of the Institute. Since 1986, the average budget has been about 4MF a year. The part strictly devoted to the network is quite small. For the last four years :

- missions for installation	200 KF
- Modem	100 KF
- softwares (SunLink and UUCP/F consulting)	80 KF
- installation of Transpac line in Montpellier, Paris, Bondy, Dakar, Lomé, Niamey	6 KF
- installation of dial-up lines (some of them shared)	
- computers, if we consider (which is exaggerated)	
that network management uses 10% of the total resources of the workstations : 15 x 10 KF	150 KF
-software and hardware for LAN (Ethernet, TCP/IP, PCNFS) : 120 x 4 KF	480 KF

### 7.2. OPERATION

The cost of a message of 1000 characters (1 KO) ranges from 0,10 FF in France to 2,50 FF when connection with the destinee is particularly difficult to reach (Ouagadougou, Bamako, Seychelles), these figures take into account failed connections.

The distant machine always takes the initiative in connection. So, remote sites pay telecommunication rates for sent and received messages. The users do not find this situation satisfactory ; a billing system that would charge to the user's account only the messages he sends is being developed.

## CONCLUSION

The particularity of the work done in the R.I.O. does not lie in experiments on new techniques but rather in the implementation of "recent but standard" technics in developing countries, with small means and on a world-wide scale.

Another particularity of the R.I.O. is its being principally intended for non computer people (90 %)

Finally, the R.I.O. is the network of a French institution but its vocation is not to be confined within laboratories walls. On the one hand the R.I.O. is open to the ORSTOM partners, that is the Universities and research institutions ORSTOM cooperates with in the developing countries. On the other, through this experience, we aim to promote the installation of research networks in those countries.

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