ASPECTS OF THE COMMUNICATION WITHIN A MULTISUPPLIERS COMPUTER NETWORK

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SUMMARY

This paper describes the existing NLR hierarchic computer network, especially the communication aspects of the datatransmission between computers of the various levels. From the user and network requirements a "most desirable" set of rules for communications is derived. The existing communication procedures are compared with the most desirable set of rules. The major part of the discrepancies, originated by this comparison, can be solved by the implementation of a programmable front-end processor.

CONTENTS

1. INTRODUCTION

The National Aerospace Laboratory of the Netherlands (NLR) has two settlements, geographically separated about 100 km (Amsterdam and North Eastern Polder).

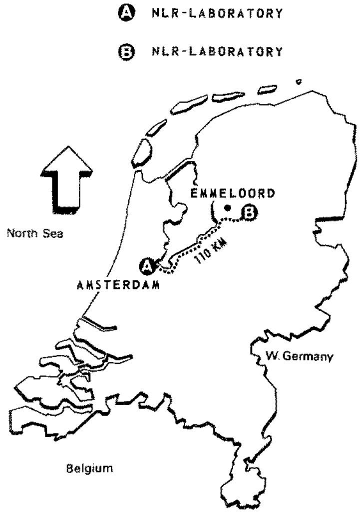

Fig. 1 Geographical location of both NLR settlements

The computer related activities of NLR can be divided into four classes:

a) acquisition and processing of data
   - a.1) windtunnel tests
   - a.2) flight tests

b) pure digital simulation
   - b.1) flows
   - b.2) structures and materials
   - b.3) operational aspects of airplanes

c) simulations with systems that contain digital computers as well as other specific hardware
   - c.1) flight simulator containing an airplane cockpit on a four degrees of freedom motion system

c.2) flight simulator containing a three axis servo driven flight table for space flight simulation

d) miscellaneous computer applications (including the management information system).

The above mentioned activities contain time critical elements. Due to the NLR philosophy to execute this type of tasks locally, three categories of computer systems have become necessary (ref. 1):

- dedicated computers for the airplane flight simulator and the space flight simulator (c)
- local or source computers to fulfil tasks in the areas of data acquisition, measurement equipment control, and real time processing: monitoring, data logging, data conversion, and quick-look mainly for windtunnel and flight tests (a, partly)
- large general purpose computer(s) for extensive data processing, pure digital simulation and miscellaneous computer applications (a, partly, b and d).

The first category (dedicated computers) is beyond the scope of this paper. For the other two categories (local computers and large general purpose computers) the historical development gives a better understanding of the motives leading to the architecture of the present network with the related problems.
In the following chapter this historical development is described; furthermore the definition of the partly solved, partly unsolved problems is given. From the problem definition and experience communication rules are derived, which may be useful to solve similar problems. The communication characteristics of the presently available network components are compared with the characteristics prescribed by these rules. Finally, the occurring discrepancies are considered as well as the measures to be taken. Moreover, NLR experience related to system responsibility, and to required computer communication characteristics will be considered in so far as they may benefit other network managers.

2. HISTORICAL DEVELOPMENT AND PROBLEM DEFINITION

The present NLR network, its development and justification is extensively described in ref. 1.

2.1 Historical development

The development of the network has started in the years 1969-1970 as a long term plan for the coming decade. In both settlements a stand-alone general purpose computer was available, the system in the settlement Amsterdam being obsolete at that moment. It was decided to realise a system with one large general purpose computer for both settlements and adequate communication and remote entry facilities. As a first step towards this objective, several measures were taken:

- the realisation of a simulation package, which enabled simulation of the obsolete computer in the Amsterdam settlement on the general purpose computer in the other settlement, communication between both settlements was achieved by a paper tape data link and by mail;
- the obsolete general purpose computer in the settlement Amsterdam was removed;
- for some activities - such as extensive data processing and large digital simulation packages - initiated in both settlements, a large general purpose computer of an external commercial data center was enlisted. In order to facilitate the use of that computer in the settlement North Eastern Polder a rented non-intelligent terminal was installed. In the settlement Amsterdam a rented process computer was installed; besides the terminal activities, this computer enabled NLR to acquire experience in the area of connecting windtunnel data acquisition equipment to a process computer;
- in September 1973 the stand-alone computer in the settlement North Eastern Polder was replaced by a larger general purpose computer provided with the most advanced communication equipment then available from the same manufacturer. Again this computer was installed in the settlement North Eastern Polder for reasons of long term planning. The connection of the rented process computer in the settlement Amsterdam was switched over from the external data center computer to the computer in the other settlement. Moreover, a local processor for flight test magnetic tape conversion activities - in the mean time installed in Amsterdam - was connected to this computer as well.

As will be seen in fig. 2, all computer elements in the network were obtained from one manufacturer, to enable that manufacturer to carry the system responsibility for the entire network.

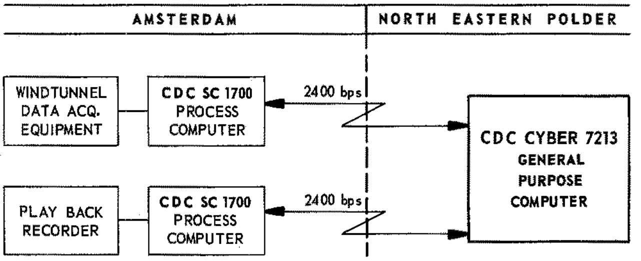

fig. 2 Network at the end of 1973

Summarizing, at the end of 1973 the first part of the system was realised: one large general purpose computer for both settlements provided with simple connections and remote entry facilities. For the next phase of the realisation of the network the following developments are important.

2.1.1. Changing attitude towards system responsibility

The windtunnel data acquisition hardware had to be replaced by local computers because of technical obsolescence and the introduction of more demanding measurement and control techniques. For cost reasons it was not attractive to select computers of the same make as the computers already installed in the network. The primary selection criterion was the fulfilment of the renovated data acquisition tasks, for the communication only the possibility of hardware connection to the available process computer was considered.

This development - connection of multi-supplier hardware - is based on a management decision. This implies that the system responsibility of the manufacturer from this moment on is limited to his components within the network. The heart of the matter is that the network manager takes at least the responsibility for the integration of the various components into a total system. NLR has accepted the system responsibility for this integration because of the in-house availability of knowledge and capabilities.

In general, there is a number of reasons, which may have a strong impact on multi-supplier's network considerations, for instance:

- historical reasons: several computers of different make are available and in use before the idea to set up a network is born;

it is necessary to insert as yet dedicated computer systems of another make into an existing network.

- technical reasons: the requirements of some specific applications are of such a nature that the manufacturer of the existing network elements is not able to meet these requirements.
- economical reasons: the price/performance ratio is bad in comparison with computers of other suppliers.

2.1.2. Workload

The workload from both settlements for the central computer had been increased.

2.1.3. Communication facilities

The Dutch PTT was able to offer more extensive communication facilities, such as voice lines up to 9600 BPS and special 48 KHz circuits for transmission speeds up to 50.000 BPS.

2.1.4. I/O facilities

More and better input/output facilities were required: terminal facilities in both settlements as well as line-printer and plotter facilities in the control rooms.

2.2 Problem definition

The above mentioned developments made it easy to predict that the capacity and flexibility of the network would not be sufficient for a long period. The demanded capacity and flexibility is expressed in the following rough user requirements:

- adequate turn around time
- data stream identification facilities
- independency of code.

Phase one having been completed (with emphasis on the implementation of one general purpose computer for both settlements), phase two is characterized by the realisation of more adequate communication and remote entry facilities. The problem definition which is in principle the same for both phases, but with different emphasises in practice, may be formulated as follows:

> Set up a network consisting of one large general purpose computer and of a number of remote entry systems (intelligent or not) from which some systems have, apart from the remote entry task, also specific local time critical

tasks, in such a way that the network will meet the user requirements.

2.2.1. Present situation

The in phase one realised communication facilities had insufficient capacity to process the total workload and to meet the demanded turn around time. To solve this problem a 48 KHz circuit (50.000 BPS) was ordered.

Also the capabilities of the in phase one rented process computer were insufficient to execute the modified and more demanding tasks within the network. The task extensions are in the areas of:

- large increase of data, offered by the local computers due to modified measurement techniques;
- increase of the number of connected processors;
- more demanding communication facilities (48 KHz circuit).

The distribution of tasks between the process computer and the local computers changed: the application oriented checking procedures are executed at the source. The above mentioned new policy concerning the system responsibility enabled an extensive market investigation. This resulted in the purchase of a computer having a good price/performance ratio suited to the communication tasks required by NLR.

To safeguard the continuity of the applications, the decision was taken to attain the solution of NLR's communication problem in three steps:

- implementation of the concentrator computer;
- implementation of the 48 KHz circuit;
- extension of the front-end communication facilities.

At this moment the first two steps have been taken.

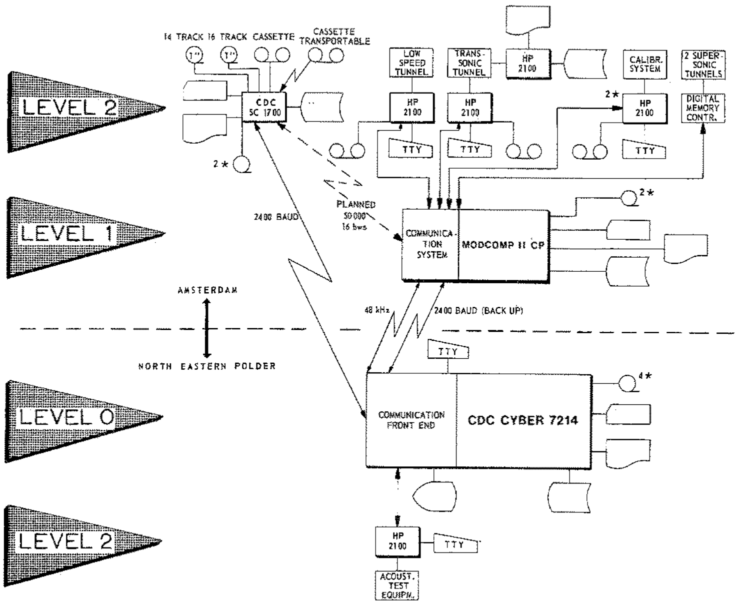

Fig. 3 Details of the present NLR computer network (April 1976)

2.2.2. Near future

In the present situation it is not possible to meet completely the user requirements, such as addressing facilities and code independency. A third step has to be taken: the implementation of a programmable front-end processor.

Making use of the experience acquired during phase one - implementation of one large general purpose computer for both settlements with simple communication and remote entry facilities - and acquired during the first part of phase two, a set of rules concerning communication aspects will be drawn up. These rules may serve as a guide for similar situations in other networks.

3. COMMUNICATION REQUIREMENTS

In this chapter the above mentioned user requirements are more fully described, the network requirements are derived, and based on the user and network requirements a set of rules concerning communication aspects of the NLR network is drawn up.

3.1 User requirements

The most determining user requirements for communication between computers are:

- adequate turn around time.
  At this moment this requirement is covered in the network, because the capabilities of the central computer, the remote communication controller, and the transmission lines are selected on an average workload of all applications. It seldom occurs that peakloads of various applications run concurrently. Moreover, the basic philosophy of the network is that time critical data processing has to be executed by local computers.
- data stream identification facilities.
  The network contains (remote) entry facilities of several types, such as batch terminals, TTY compatible terminals, and local computers in various control rooms of experimental facilities. Furthermore, it contains (remote) output facilities at several locations such as terminal sites and control rooms. Data, submitted by the entry facilities, must be processed by the central computer in the settlement North Eastern Polder, and the results must be presented at an output facility selected at wish. It is therefore necessary to have the capability to send information (via the central computer) from each input device in the network to any output device, on certain security conditions. This implies that every block of data to be transferred, has to be provided with sufficient identification.
- independency of the code.
  For some applications it is not possible to execute code conversions with the available equipment. In some applications the large amount of data to be transferred requires the most efficient transmission code in order to limit transfer time and thus turn around time. This implies either the possibility to transmit arbitrary bit patterns or conversion capabilities.

3.2 Network philosophy and entailing requirements

The network philosophy, related to the communication aspects of the existing network, is:

- the suppliers of the various components of the network keep system responsibility for their own hardware and software. The network manager is responsible for the integration of the components into the network. This principle leads to the following requirements:

  . the selection of communication hardware and software should be based on general purpose I/O facilities such that interfacing with other components can be done without complex modifications.
  . arrangements should be embedded in the contractual matters concerning supplier's approval of the possibly necessary modifications and adjustments.
  . the network manager should have at his disposal equipment and procedures which enable him to locate malfunctions within the network.

- the remote communication controller is regarded as a functional part of the central facility, because both settlements should have equal access to the central computer for off-line batch processing and on-line connection of data acquisition systems. This implies that data streams, submitted to the communication computer, should have the same characteristics as the data streams directly submitted to the central computer. This leads to the following network requirements:
  . data, submitted by local computers to the remote communication controller, must be complete jobs, as if submitted directly to the central computer. This implies that, apart from the measurement data, job control information should be provided as well. In general, this information (such as accounting info, type of processing indications, device and/or file identification) is only available at the source.
  . preparation of data blocks to be transmitted has to be done uniformly for the entire network according to the line protocol, selected for the communication between the central computer and the remote communication controller. This preparation includes addition of information about addressing, about type of code, and for transmission error detection. This implies that only one error detection method will be used for the entire network.

3.3 "Most desirable" set of rules

The user and network requirements result in the following "most desirable" set of rules for communication in the NLR network:

A. The addressing facilities should be sufficient.
B. It should be possible to transmit arbitrary bit patterns.
C. Data, submitted by local computers, should be in the form of complete jobs.
D. Preparation of data blocks to be transmitted should be done uniformly for the entire network, according to some selected line protocol.
E. Consequences of interfacing should be taken into account, when selecting communication equipment.
F. System responsibility arrangements in the contract should include arrangements concerning modifications and adjustments related to interfacing.
G. Network test equipment and procedures should be developed.

4. COMMUNICATION EQUIPMENT: SURVEY AND COMPARISON WITH THE RULES

In this chapter the characteristics of the communication equipment within the network will be enumerated and compared with the "most desirable" set of rules. The last rule can not be considered, as this rule concerns the entire network. Attention to this rule will be paid in section 4.4.

4.1 Central computer communication equipment

The central computer - a CDC Cyber 72, 64 K words main memory and 460 M bytes background memory - is provided with two types of communication devices:

- Device that supports serial asynchronous communication lines (110-1200 bps) and synchronous lines (up to 4800 bps).

Rule	Available	According to rules
A. Addressing	108 data streams/line	yes
B. Arbitrary bit patterns	ASCII or BCD per line	no
C. Complete jobs	not applicable	-
D. Uniform blocks	yes, LPC error check	yes
E. Interfacing	not applicable	-
F. Contract	not applicable	-

Table 1: central computer low speed comm. device characteristics

- Device that supports serial synchronous lines (up to 50,000 bps).

Rule	Available	According to rules
A. Addressing	5 data streams/line	no
B. Arbitrary bit patterns	ASCII and free format	no
C. Complete jobs	not applicable	-
D. Uniform blocks	no, CRC 16 error check	no
E. Interfacing	not applicable	-
F. Contract	not applicable	-

Table 2: central computer high speed comm. device characteristics

4.2 The remote communication controller communication equipment

This computer - a MODCOMP II CP, 32 K words main memory and 20 M bytes background memory - is selected especially for communication purposes. Four types of communication devices are connected, supporting:

- serial synchronous lines (up to 250,000 bps)
- serial asynchronous lines (up to 19,200 bps)
- programmed I/O 16 bits parallel lines (up to 5,000 words/sec.)
- 16 bits parallel lines with direct memory access (up to 50,000 words/sec.).

In table 3 the characteristics of all types will be included.

Rule	Available	According to rules
A. Addressing	programmable	yes
B. Arbitrary bit patterns	yes	yes
C. Complete jobs	not applicable	-
D. Uniform blocks	programmable	yes
E. Interfacing	yes	yes
F. Contract	yes	yes

Table 3: remote concentrator comm. devices characteristics

4.3 Local computers communication equipment

Referring to the communication equipment and procedures the local computers may be divided into two categories.

4.3.1. Hewlett Packard 2100 program controlled 16 bits parallel I/O

This communication equipment is developed by NLR.

Rule	Available	According to rules
A. Addressing	implicit	no
B. Arbitrary bit patterns	ASCII	no
C. Complete jobs	no	no
D. Uniform blocks	no	no
E. Interfacing	yes	yes
F. Contract	no	no

Table 4: HP 2100 comm. device and procedure characteristics

4.3.2. Control Data SC 1700 16 bits parallel I/O with direct memory access

This communication eqüipment is developed by NLR.

Rule	Available	According to rules
A. Addressing	yes	yes
B. Arbitrary bit patterns	no	no
C. Complete jobs	yes	yes
D. Uniform blocks	yes, LPC error check	yes
E. Interfacing	no	no
F. Contract	yes	yes

Table 5: CDC SC 1700 comm. device and procedure characteristics

4.4 Network test equipment and procedures

The test facilities should enable the network manager to check separate components (such as various computer parts, modems, communication lines) and interconnected components up to the entire network. Depending on the status of the network (in development or operational) test activities will generally begin with the separate components in the case of development and with the entire network in the case of an operational system. Although test procedures in these cases may be different, the test equipment may be the same.

The test facilities under the responsibility of the NLR network manager may be divided into two categories:

- tools locating malfunctioning components, such as:
  - wrap around facilities;
  - line test equipment;

- network diagnostic software.

This type of tools is sufficient as long as it concerns manufacturer's equipment tools locating malfunctions within components, build by NLR, such as:

- static input simulation equipment;
- dynamic input simulation equipment;
- dump analyzer.

5. TECHNICAL SOLUTION

In the last chapter a number of discrepancies has been revealed between the communication device and procedure characteristics, and the requirements of the "most desirable" set of communication rules. These discrepancies are related to the communication devices of the central computer, and to the communication facilities and procedures of the local computers; because the remote concentrator has been selected in accordance with these rules, there are no discrepancies.
The discrepancies related to the communication devices of the central computer are due to the lack of flexibility of this equipment, because of which adjustments to increasing and more severe requirements can not be realised. The communication devices of the central computer consist of a hardware multiplexer and a firmware communication station; both devices are not programmable. The present problems - for the high speed device: insufficient addressing facilities, intransparency to the code, and context depending block formats; for the low speed device: intransparency to the code - can only be solved by implementing a programmable front-end processor, as the third step of the in section 2.2.1. described phase 2.
The discrepancies related to the communication facilities of the local computers, are mainly due to the procedures. These discrepancies may be eliminated by modifications of the procedures; however, this may bring on a too heavy workload for the local computers. A trade-off study is required. The most important question of this investigation concerns the selection of the transmission block error check method. Based on the experience with the 48 KHz circuit (until this moment) NLR prefers to implement the cyclic redundancy check (CRC 16) method (generating polynominal is $x^{16} + x^{15} + x^2 + 1$) for the entire network instead of the longitudinal parity check (LPC) method; communication oriented computers have the ability to accumulate such check characters in hardware. The presently connected local computers do not have this ability, therefore the accumulation of the check characters has to be done in software.

6. CONCLUDING REMARKS

It can only be recommended to carry the system responsibility for the integration and management of a multi-suppliers network, if sufficient knowledge is available in the areas of the relevant applications, the hardware and software features of the components, and hardware and software interfacing techniques. Attention should be paid to the contractual agreements with the suppliers.

The NLR network is realised in phases, because of budget and continuity reasons. This approach has proven to be attractive, as it enabled effective tuning of the network to the application package. In each phase advantage could be taken of the experiences acquired during preceding phases.

When selecting local computers, (possibly) to be inserted in a network, it is recommended to add the communication requirements to the selection criteria. The presently obtainable minicomputers enable such an approach.

The major part of NLR's communication problems can be solved by implementation of a programmable front-end processor. When selecting a programmable front-end processor, attention has to be paid to the critical elements of the interfacing. It is recommended to consider the front-end processor together with the coupler as one component as far as system responsibility is concerned.

7. REFERENCE

W. Loeve — An hierarchic multi-suppliers computer network of a research laboratory with two settlements.

Paper presented at the combined American European CDC-users conference in Amsterdam, 1975
NLR MP 75012.