Recommendations for the Use of Fieldbuses at CERN in the LHC Era

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Abstract

Throughout the LHC project fieldbuses will be required to connect and control equipment and devices of various types. It will be necessary to integrate both industrial equipment and custom designed devices. In order to increase efficiency of resources a CERN working group recommends restricting the choice of fieldbuses, to be used in the years to come at CERN and by the various institutes collaborating in the LHC project , to three : CAN bus, PROFIBUS and WORLDFIP. After the selection phase, the three fieldbuses are now in the acceptance phase.

1 Objective

Fieldbuses will be used extensively to control and monitor equipment in the LHC experiments, in the LHC machine, in up-grading the control systems of other machines and in various general purpose installations. A single fieldbus may not satisfy all the users, however, CERN cannot support all the fieldbuses likely to be available on the market. A plethora of fieldbuses are proposed by various standardisation bodies and by industry. In order to reduce design time, installation cost and later maintenance effort, the number of fieldbuses used in the integration of equipment must be reduced to a minimum.

For this purpose the CERN Controls Board at its meeting of September 13, 1995 created the Working Group on Fieldbuses in controls . The objective of this working group was to define a policy for fieldbuses to be used in the years to come at CERN and by the various institutes collaborating to the LHC project. The domain of application should cover both machines and experiments requirements. The working group on fieldbuses comprises 12 members representing all the controls activities at CERN

2 Investigation procedure

2.1 Notion of fieldbus

The term fieldbus refers to data transmission systems used to federate or integrate rather simple equipment to be remotely monitored and controlled. Fieldbuses should not be confused with local area networks (LANs) although in some cases their domains of application may overlap. Both are used in process control architecture.

Fieldbuses can be hierarchically divided into three major groups: a full-size fieldbus (the closest to LAN), device bus and sensor bus.

Device buses and sensor buses are used at low level to connect intelligent devices or intelligent sensors respectively to programmable logic controllers (PLCs) or to front-end equipment . At this level the communication is usually periodic and deterministic especially if close loop control systems are involved. At the higher level fieldbuses transport data between the PLCs or front-end equipment and the supervisory station or various types of engineering stations. At this level the transmission is more on-request oriented and could alternatively use LANs.

2.2 Scope of application

The investigation of needs was rather wide . The needs of accelerators and experiments must be considered for both commercial and custom made devices. As a large part of the equipment for the LHC experiment will be provided by industry and national laboratories, standardisation must be general enough to be accepted by the majority of the users. It is not at all obvious whether these quite stringent constraints can all be met at once by the recommendations of the Working Group. It also needs to be seen how much incentive can be created in order to have the recommendations widely accepted. In any case a project of the size of LHC cannot be started without clear guidelines in this field.

So far four main types of application are identified:

I) Industrial controls with a limited number of parameters (say 10 to 1000) which do not change often and possibly including closed loop feedback with a PLC. Reliability, robustness and also redundancy are the main requirements for these applications.

ii) Laboratory equipment for complex control procedures involving workstations over distances up to 100 meters. Flexibility and modularity are needed. The data rate may be very high.

iii) Sensor readout and actuator control with a very large number of parameters (more than 100,000) up to 500 metres. Very low price per node, mechanical robustness, easy addition/removal, degraded operation and interchangeability are requested.

iv) Home built electronics to be installed inside the detectors. The main problems are: limited space, low power dissipation, high radiation level, harsh electromagnetic environment and a very large number of elements (more than 100,000).

2.3 Selection criteria

A technology-minded working group tends to select products purely for technical reasons. This was common practice at CERN in the past but the economic situation has changed. Fieldbuses are part of a fast evolving technology where industry nowadays plays a leading role.

CERN has invested much effort in the past in the development of fieldbus related equipment (e.g. Mil 1553 B bus, etc.). It is now agreed that a CERN specific system can no longer be promoted. Even though the perfect match cannot be found, a CERN specification will not be considered.

We will promote standards and products which are commercially available and are likely to be supported by industry in the long term and at the same time fit our needs and are compatible with our constraints. Well documented open systems based on recognised standards should be preferred. Proprietary systems are to be avoided.

In order to better know the availability of products a questionnaire was prepared to help in the discussion with vendors. A similar exercise was carried out at DESY.

2.4 Technical requirements

The technical requirements of the accelerators and the experiments have many common points. However there are some exceptions like the fact that the LHC machine needs to cover long distances whereas the experiments' needs are locally confined.

The main points to be considered are:

- Open system to avoid proprietary systems.
- Industry standards which have a proven acceptance by European industry.
- Wide range of commercial products available (from chip sets up to complex nodes, including software and development systems).
- Cheap connections (including cabling, connectors, interface electronics, software).
- Capacity for reliable remote hardware resets and remote diagnostic facilities in non accessible areas specially in the experiments where radiation levels may be very high.
- Robustness
- Determinism.This notion is of great theoretical importance in the design of fieldbuses and LANs. The limits of response time must be clearly stated. In the experiments we usually do not have problems however in the LHC machine this point is of paramount importance to control the magnet currents for example.
- Bus mastership
  The notion of multimastership is considered to be of interest in some cases, but polling may also be of interest in some cases. The capability for each node to be able to transmit a message to any other node of a bus is the important feature.
- Redundancy
  This feature is more and more required in magnet and cryogenic control systems. Fault tolerant systems will be needed in some limited access environment.
- Coverage
  The distance normally required should fit an experimental hall or an experimental cavern, 100 up to a maximum of 500 metres should suffice in practice. Within the large machines this distance must be extended up to 1000 metres. There are some cases in the LHC machine environment where distances of 30 km must be serviced (e.g. SPS/LEP reboot and configuration links).
- Throughput, bandwidth
  Instead of expressing the throughput in terms of bits per second, it is most appropriate to express the throughput in term of actions required per second regardless of the implementation of the physical layers and of the driving software.
- Galvanic isolation
  This feature is an essential part of high quality transmission specially for lengths over 100 mmetres and for heavy duty equipment (e.g. kicker magnets) creating harsh environmental conditions.
- Radiation hardness
  At the sensor or actuator level in some LHC detector environment the radiation dose may reach up to 500 Gy integrated over 10 years, the neutron flux may be as high as 10**13 per square centimetre.
- Magnetic field environment
  Some equipment will have to operate in magnetic fields reaching 1kG which poses serious problems for coils, transformers and DC-DC converters.
- Low power dissipation
  In some detectors the power dissipated by the electronic devices must be kept to a very low level.
- Time scale
  The system will have to be operated for at least 10 years and accessibility may be limited in time.

2.5 Cost considerations

The machines and experiments are getting more complex and are increasing in size while, on the other hand, staff and budgets are reduced. The cost considerations are extremely important especially as fieldbus equipment will be used in large quantities. It is important to consider the global costs involved, i.e. prices for hardware and software as well as manpower for configuration, installation and maintenance. In this context it is clear that well proven industrial solutions should be considered first. Furthermore, due to cost considerations it is necessary to cater for simple low cost solutions for trivial and large scale applications in addition to the solutions needed for more complex applications.

2.6 ESONE workshop[1]

In order to better evaluate the state of the art in industry, a first workshop on fieldbuses in collaboration with ESONE took place at CERN on 18 and 18 March 1996. During this workshop presentations from industrial firms proposing either proprietary systems (InterBus-S, Lonworks, PDV-BUS) or open systems (CAN bus, PROFIBUS, WORLDFIP) took place. Other national laboratories (DESY, SACLAY, KFA, GSI, NIKEF and EPFL) also reported on their experience and plans. The questionnaire on fieldbuses was used to get comparable results from the various manufacturers.

2.7 Other standardisation efforts

There are currently many fieldbus standardisation efforts under way around the world:

FIELDBUS FOUNDATION[2]

The Fieldbus Foundation consortium is contributing to the IEC/ISA efforts to define an international standard. This seems a far reaching goal and many years will be required before an agreement is reached and practical products are made available. However, we cannot wait for future possible standardisations, so we have adopted a pragmatic approach and consider only existing and proven products.

CENELEC[3]

The European Fieldbus Standard EN 50170 was ratified in Brussels on March 15, 1996 under the auspices of CENELEC, a European standards organisation. The standard concerns three fieldbuses: PROFIBUS (the FMS and DP layers , the PA layer will be integrated later), WORLDFIP and P-NET. According to European Standardisation rules EN 50170 is accepted in 18 participating countries of the European Union, even in those that voted against it. The existing national standards (DIN 19 245 for PROFIBUS in Germany, UTE 4660 for WORLDFIP in France and DSF 21906 for P-NET in Denmark) was withdrawn by June 30, 1997 and replaced by EN 50170.

NOAH[4]

The goal of the NOAH project under the auspices of CENELEC is to define the necessary elements to allow the industrial use of distributed application across P-NET, PROFIBUS and WORLDFIP fieldbuses (fieldbus standard EN 50170).

3 Recommendations

3.1 The proposed buses

The Working Group recommends the following three fieldbuses: CAN bus, PROFIBUS and WORLDFIP.

PROFIBUS and WORLDFIP should ultimately be made compatible at the application level through the CENELEC standardisation effort. We don't know yet whether CAN will also benefit from this standardisation effort.

As far as the applications are concerned CAN bus should mainly be used at the device and sensor levels while PROFIBUS and WORLDFIP should mainly be used for more complex control tasks although they can also be used at a lower level. We will now discuss their relative merits.

The main characteristics of the three recommended fieldbuses have been listed to the best of our knowledge for comparative purposes[5].

3.2 CAN Bus (Controller Area Network)[6]

This industrial bus was primarily intended for the automotive market, it meets high requirements for the reliability of data transmission. It was developed by the BOSCH company in Germany, it can be used as an open system without the need to pay any licence fees. It is mainly based on the ISO 11898 norms. It complies with the following standards: ISO/TC22,SC3/WG1, N427EISO. It was also standardised by the SAE (American Society of Automotive Engineers).

It is now used in many non-automotive industrial applications (e.g. controls of production lines and machine tools, medical apparatus, textile machines, mobile and stationary agricultural and nautical machinery etc.). It enjoys wide acceptance by industry and research laboratories. Chips are available and are mass produced so they are cheap and reliable but not radiation resistant. Due to the requirements of the automotive market they will be available for a long period of time. For the time being only the two lower ISO layers (physical and data-link) are defined. Many manufacturers are proposing layers on top of the standardised ones (e.g. DeviceNet) although it is clear that the latter must be considered proprietary.

This bus is already in use in ATLAS[7] and CMS plan to use it soon. It is used for real time control applications.

3.3 PROFIBUS (PROcess FIeld BUS)[8]

PROFIBUS is the result of a project funded by the German Federal Ministry of Research and Technology[9]. It can be used at three levels: FMS, DP or PA to better match the application. It is well developed and supported by large companies such as SIEMENS. It complies with the DIN 19245 Standard, part 1 and 2. It already has a wide acceptance in European and American industry.

PROFIBUS can work in multimaster or in master /slave mode. PROFIBUS FMS is suitable for communication between intelligent stations (e.g. PLCs or PCs). PROFIBUS DP is optimised for fast and efficient data transmission between controllers and the decentralised periphery (e.g. sensors). Baud rates can be selected from 9.6 kBits/s up to 12 MBits/s. PA can be used for application in intrinsically safe areas.

Presently PROFIBUS has more than 1,000,000 installed nodes, 1000 products are offered by 650 vendors in 17 countries.

PROFIBUS can be found in many industrial control applications at CERN.

3.4 WORLDFIP(Factory Instrumentation Protocol) [10]

WORLDFIP complies with the UTE-C-46-601 through C-46-607 French norms available from AFNOR. It is a system based on a centralised access method where one Master continuously distributes the access right (token) to the different stations. WORLDFIP provides data transfer services for cyclic variables, event variables (acyclic) and messages in a send-and-request series of application functions (a subset of MMS[11]). WORLDFIP supports three standardised transmission rates: 2.5 MBits/s for fast real time operations over short distances using twisted pair cables or optical fibres, 1MBit/s the standard operation frequency for twisted pair cable at distance less than 500 metres and a low frequency of 31.25 kBits/s for long segments up to 2000 metres. An additional frequency of 5Mbit/s was specified for optical cable transmission [12].

It is presently installed at SACLAY and it is planned to use it for the LHC magnets controls [13].

4 Acceptance of the recommendations

In order to create some incentive to use the recommended fieldbuses as widely as possible, technical, administrative and commercial support will have to be set up at CERN . This support should be limited to the three recommended fieldbuses.

4.1 Training

According to the real needs of the users practical courses by experts on CAN were organised at CERN. Courses on PROFIBUS will be organised soon.

4.2 Practical developments at CERN

A CAN bus driver was tested in an EPICS environment by the controls expert of the ATLAS experiment.
A set of models showing connection capabilities of the three fieldbuses was developed in the LHC division and presented at the second workshop.

4.3 The second workshop

A three day workshop and an industrial exhibition limited to the three recommended fieldbuses were held at CERN on 16 to 18 September 1997. This workshop permitted an important exchange of information between users of fieldbuses at CERN and experts from industry. The needs of CERN and the capabilities of the buses were both expressed. The results can be summarised as follows:

[1] The three recommended fieldbuses meet a large part of CERN requirements,

[2] They are supported by industry and products are commercially available,

[3] None of them can cope with the radiation hardness requirements of the LHC experiments
(only the 1553B fieldbus presents such a feature)
therefore special actions will have to be envisaged,

[4] Some problems related to high magnetic field environment still remain for the LHC experiments, none for the LHC machine,

[5] Power dissipation problems still have to be addressed,

[6] Some new actions were identified during the post mortem meeting held after the workshop.

4.4 Special WORLDFIP seminar

Subsequently a special workshop on WORLDFIP was organised at CERN for potential users. The WORLDFIP experts and CERN experts could discuss the opportunity to use WORLDFIP for the real time control system of the LHC magnet currents which is a fundamental issue for the LHC machine.

Some needs concerning the RF systems were explained though the needs for LHC in the matter are not yet well known.

The RF experts gave their view on interoperability of devices and requirement of commercial development systems for WORLDFIP.

4.5 Upper layers of CAN

For the time being only the two lower layers of CAN are standardised, we still have to define what should be recommended above these two layers. We will also define profiles for fan trays and high voltage power supplies as well. A special seminar will be held at CERN as soon as possible to address these problems.

4.6 Expertise at CERN

The expertise on the three recommended fieldbuses will be ensured by three different expert groups which already use the fieldbuses in question in a running project. The experts will also ensure a technical liaison with experts from industry.

4.7 Exchange of expertise

An already existing user group will be used to ensure a constant exchange of information between people having activities linked with fieldbuses.

4.8 Purchasing

Given the large amount of modules to be purchased by CERN and the various collaborating bodies, centralised negotiation and purchasing procedures should be set up.

4.9 Radiation hardness

This problem must be addressed in close collaboration with industry, LHC experiments and universities involved in these activities.

5 Conclusion

The Working Group on Fieldbuses recommends restricting the choice of Fieldbuses to be used in the years to come at CERN to the following three : CAN bus, PROFIBUS and WORLDFIP.

This proposal is mostly for pragmatic reasons. It could be reviewed if significant development takes place in the fieldbus domain .

The necessary steps to have these recommendations widely accepted by the community are being done and the three fieldbuses start to enjoy a wide acceptance.

An effort is still requeired for the commercial support. Training has already started via the CERN technical training service.

References

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