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TRENDS IN REAL-TIME COMMUNICATION NETWORKS ONBOARD SHIPS.

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Abstract

This paper gives an overview of ongoing EU-founded project within the area of developing and standardization of communication standards for safe critical communication standards for integrated ship control, namely ATOMOS I/II and DISC I/II..

1. INTRODUCTION

In the 90's an EU funded project ATOMOS (Advanced Technology for Optimizing Manpower Onboard Ships) has been running. The project ended with success in 1994 and the successor ATOMOS II is going to end in December 1998.

As the first ATOMOS project the second ATOMOS encourages many aspects within the area of ship control (see http://www.atomos.org). A part of this project is subtasks 2.1 and 2.2 which is going to be presented in this paper with focus as described above.

- Task 2.1 Architecture and Reference Model of ISC systems
- Task 2.2 Data Distribution aboard Ships.

This work is intended to be finish late 1998.

2. NETWORKING

The networking part of the ATOMOS project started as technology driven project with a high focus on developing a high performance fault tolerant communication system for time critical applications with incorporated diagnosis system.

Globally the area of communication systems for control purposes is still not stable. All though EN 50170 has been formulated with P-NET, profibus and world-FIP and a combining "glue" standard which should ensure easy communication between the above mentioned substandards it is still not released (EU project RACKS). So it is easy to understand that standards are not easy to develop.

The three above mentioned communication protocols all gives a "total solution" from layer 1 to 7. As seen in history the technical evolution on the lower layers (in communication protocols) goes fast whereas higher level protocols seems to remain. One good example is the TCP/IP protocol stack. Today it can be driven by ether-net, arc-net, serial lines, ATM, FDDI, serial lines etc. Functionality on the top level do not change if we do not mention performance (not discussing which metric/performance measure(s) is the basis). Proprietary solutions for control networking do often reflect the idea behind the control equipment from the vendor instead of conforming to a accepted open standard. The idea behind this concept is "well known".

Control equipment is ranging from dumb PLCs up to powerfully systems based on a real-time operating system like small proprietary kernels, QNX, WindRiver and similar products. Lately equipment based on office automation products (windows 95/NT) has also entered the area. This variety set up different needs like:

- Remote VERY fast I/O (PLC)
- Remote control, down load etc
- Fail-resilient real-time control networking.
- Distributed system for operator use
- Intra-net for www based ship applications
- "Non" real-time applications like maintenance products

It is obvious that "one" standard can't cover the entire spectra. One example: TCP/IP on a 10 Mbit/sec ether net can give very high bandwidth for transport of information - up to 75% of the bandwidth. But for "transport" of short time critical commands like "open shutter 10", "read dig input 23" there can't be given reasonable response time guarantees to ensure proper quality of the remote reading for integral use in a control loop when dealing with kHz loops or even slower. Priority based communication can and is often implemented at the driver level which means that outgoing and in-going communication can be queued according to some given static or dynamic rules. But when looking at the network nearly all network can be viewed as a non priority non-preempt-able transport mechanism. So if traffic considerations encourages the network (and if not it is of no use). If the network is going to be used for time critical communication a pessimistic worst case estimate/verification is the only valid way. A seen in the paper by Schiler et al this will impose restrictions on the traffic patterns from the individual nodes that it is nearly not possible to integrate non-real-time traffic.

The chosen station operating system do also has a major impact on real-time performance. Supplying a 1 kHz sample rate system with a max wow/flutter on 2% max deviation must be less than 20 msec. Although 20 msec is long time certain station operating systems can have serious problems to fulfill this demand.

3. TWO LEVEL MODEL APPROACH

In ATOMOS II as well as in DISC II this problem sphere has been divided in two: The basic transport mechanism (ISO layer 1 to approx 4) and the application profile interface. In short named T-profile and A-profile. The main goal behind this is to obtain a simple layered concept with the possibility to interchange the T-stack or the A-stack without "any" interference with the other layer. If this philosophy is held against the statements just above some difficulties to obtain this goal is obvious. Later in this paper "metrics" for control network is discussed. If two profiles is 100% interchangeable they must have the same metrics. This is often not the case.

3.1 *PROFILES*

To give the possibility to integrate different networks (based on "gate technology") the two layer model (A- and T-profile) has been proposed within ATOMOS, DISC as well as PISCES. The main objective is to describe different profiles given the above mentioned demands, and have the opportunity to integrate "old" standards.

T-profiles are described by:

- (Un)reliable parcel service
- Broadcast/Multi cast facilities
- Routing
- Fault tolerance
- Performance metrics
- Simulation/verification tools for communication pattern analysis.

Just to illustrate the complexity imagine 5 different T-profiles (like P-NET, Profibus, World-Fip, CAN-BUS, ATOMOS net) and five different A-profiles (like EN50170 vol-1, vol-2,vol-3). Just by combining straight this gives 15 networks with different metrics.

This is of course not operational when setting equipment together so another selection scheme must be applied.

A twofold approach is described in the following:

- Conformance class approach for describing components and sub-systems.
- Real-time guarantee characteristics.

The conformance class approach gives a application driven setup of demands for the control network. Like 2000 cooling containers which each wants to communication 3 times a minute with 245 bytes of log info setup communication demands for the cooling section network environment.

Real-time qualities is the major driven factors in network for control purposes. Office automation networks overall goal is to deliver wanted service "as fast as possible". Control network on the other hand often sets delivery demands like "read A within 0.5 msec from now" or worse. Values are characterized with quality based on metric value and delivery time. Another paper on this conference from the authors of this paper elaborates on this issue.

The outcome shall then be basis for a simulation/verification to ensure that the design has succeded.

In the following these two approaches are presented.

3.2 *Architecture and Reference Model of ISC systems*

To ensure high quality and easy reliable consistent design and configuration of "a ship" it has been proposed to develop a scheme for reference modeling and conformance class development(Mikkel Hede, 1997). Reference models state the context where the model is located and under which constraints and "performance index" the model is located. Like a reference model can describe communication activity based on traffic generating models for components hooked on the control network. In this scope a conformance class for pumps can give how the pumps is presented on the network and the activity in this context. A dumb conformance class can supply with start/stop/init on and a more intelligent pump conformance class can expand with possibilities for measuring flow, runtime counters etc. The bearing principle is that putting components together can be successful if both sides conforms to a given conformance class on the specific connection. Verifying behavior is also intended to be a part of this because a total system description can be manipulated for extraction of behavior combined with the relevant metrics for the communication network can lead to a formal verification of correct layout of communication. This implies introduction of priority of communication etc to ensure preemption of low priority information flow. In ATOMOS II a case study "Proposal for Companion Standard for a Main engine" in subtask 2.2 is used to "test" the functionality of the selected approach. This work is expected to end late 1998. Preliminary internal results shows that a proper conformance class and reference model approach shall cover at least the following disciplines:

- Subsystem supervision/control/safety interface
- Relevant decomposition of the above mentioned:
  - Auxilary functions
  - Ship Alarm subsystem
  - Power interface
- Demands for external relations (I/O, performance etc)

An important issue is state diagram modeling of the command interface for later possible overall verification of the total system viewed. For this a syntactical state modeling language like UML is likely to be chosen.

In a long term it is regarded as a must that the actual configuration of the ship based on verified conformance classes gives the sound basis for a functional verification of the ship performance and safety. This will consist of a pure logical state verification and probably a stochastic time/performance evaluation. It is expected from the authors view that classification societies will come to play an important role in this area.

3.3 *Metrics*

In the first place it is not so difficult to formulate a an A-profile interface with for all parts useful l functionalities. In short it can often be described as read,write,subscribe, down/upload, start/stop, create/delete. The problems arise when the discussion falls on data types. The popular object oriented approach can in many cases be disregarded as potential because often many nodes are more or less dumb PLCs which do not much more than byte,int,float, strings and combinations hereof. But this problem is to be solved. The problems first really comes to the surface when discussing performance. Performance can be viewed as a metric under certain constraints like:

- Network speed.
- Transmission characteristics.
- Hard timing characteristics.
- (Predictable) behavior in error situations.
- Model of traffic and imposed load on the network.

The chosen metric will often depend of if the network is going to used for:

(1) Data collection.
(2) Commands for equipment.
(3) Critical command issuing.
(4) "Fast" closed loop control (up to 1/10/100/1000/... Hz).
(5) High reliability through redundancy
(6) Efficiency of non-normal behavior.

The first items are regarded as the easiest to fulfill and the last as the most difficult to fulfill.

In the ATOMOS project the goal has been to fulfill all the items giving the opportunity to introduce critical closed loop control under certain constraints.

4. SELECTION OF A-PROFILE(S)

While the idea is to have multiple A-profiles ATOMOS II has selected EN50170 vol 1 (P-NET) to give the facilities/commands of layer 7. The EN50170 vol 1 has been chosen because of its simplicity. In ATOMOS II the main use of the network is for time critical communication rather than bulk transfer of information (log file transport etc). The protocol itself is relative simple and therefore possible to implement for different vendors.

To ensure smooth-less integration up against more than one T-profile a standardized interface has been chosen according to the OSI model, namely "Service Access Point"(in short: SAP) methodology. In short this is a connection oriented philosophy with transparent transfer of information. On layer 4 read and write access points can be defined. The idea is that the SAP mechanism do not recognize the content of the data packages but do only deliver them correctly. So the A-profile holds the total EN50170 vol 1 engine. The A-profile is in this model free of timing but must "be fast as possible". It is possible to estimate time consumption in the A-profile so a total timed description of the network can be formulated. Because all access is done as referenced no unknown time when doing search is "present" in the A-profile. This work is going on in autumn 1998.

4.1 *T-profile*

Several basis T-profiles was available. EN50170 vol 1, ATOMOS I T-profile, TCP/IP on ether net etc. The original ATOMOS network are based on a dual ARC-net to ensure fault tolerance. On layer 4 the user is presented for a single SAP connection facility total hiding redundancy handling. The design also includes integration a low cost nodes with no redundant network interface, of course with a reduced guarantee for safety. In the T-profile the metrics for safety, redundancy, timing behavior etc is located. Using ARC-net - a token based system - worst case timing can be deducted and given a formal modeling of the T-profile safety/behavior calculations can be performed giving results like "Node 4 can not have it demands for traffic fulfilled". In this case traffic is "pure data communication" on layer 1-4, modeled in packages of their individual size. There is some of course restrictions on modeling traffic. In general more "trivial" or uniform over time the traffic can be modeled more accurate modeling can be performed (stochastic or noisy traffic can also be within this scheme). This work is ongoing in 1998 and preliminary results is showing interesting results. (paper submitted for CAMS98 by H. Schiler et al). In short giving traffic characteristics and (multi segment) network characteristics guarantees can be given under certain constraints. The goal is to end up with a modeling paradigm for the ATOMOS A- and T-profile. Because it is unrealistic to model and verify all problems in the world restriction has been put on traffic patterns as well as network technology. The paper "Traffic Analysis for Real-Time Communication ." gives this much more detailed and will not be referred more in this paper.

5. OTHER PROJECTS

MiTS is a Norwegian project which deals with development of a network for smooth-less integration of subsystems onboard a ship. The main difference between ATOMOS network and MiTS is that MiTS is based on TCP/IP. In many ways an interesting selection. This selection gives very different goals in defining a metric for the network. TCP/IP's main goal is to ensure liveness for all communication disregarding static or temporary change in "hole through". This is the main principle of TCP/IP networking. This gives problems when looking at hard real time behavior. No one can ensure proper timing on a TCP/IP network so closed loop control is "impossible". So is use for safety critical communication because lack of redundancy and timing guarantees. On the other hand logging communication and interconnection to office automation equipment is smooth-less and many of the "duties" onboard a ship can be done on such a network.

The ongoing EU project PISCES is now to be attended by partners of the ATOMOS consortia. The goal is to end up with a European A-profile layout and a number of T-profiles supporting the A-profile. This work is starting mid 1998 and of course positive result are expected. DISC II (Demonstrator for Integrated Ship Control) is a joint venture project with participants from ATOMOS, MiTS etc. The goal is as with the cooperation with PISCES to end up with a European suggestion for a standardization for:

- Communication:
  - A-profile
  - T-profiles
- Construction of a mockup to demonstrate integration in live.
- Continuation of standarization work

6. CONCLUSION

The ATOMOS project has shown interesting results and gives a trend for future work. The cooperation between PISCES (Granum, 1997), DISC II and ATOMOS shows in this prelimeray phase a good spirit which indicate positive results in the next year and two. The result is likely to be a multi-stack multi vendor communication standard(s)

The litterature only gives a brief overview of documents produced in the consortias due to confidentialy clauses. This will hopefully change in late 1998.

7. REFERENCES

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"only the authors are responsible for this paper and do not speak on the behalf of DISC/ATOMOS or PISCES".