SPECIFICATIONS FOR A POWER MANAGEMENT FIELDBUS

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Abstract— One of the major challenges at the moment is the improvement of the present power system. The traditional power industry is outdated, but the responsibility is not just in the utility side. The consumer is being forced to perform a high quality load and ration the power consumption. A way to improve the power system is turn it intelligent, through a network. In this study, we analyze the features of a set of control fieldbuses and summarize the main features of a specific fieldbus for power management.

KEYWORDS

Communication systems, distributed control, and power management.

I. INTRODUCTION

The power management is an important question to be issued in the present moment and in the future. Both consumer and utility sides must be aware of the power quality, because today the efforts to change the scenario are not just in the utility side, but also in the consumer. In order to control the quality of the power in a rational way, the information of power factor, total harmonic distortion, demand factor, and so on, of each consumption point need to be shared. To do so, it is necessary a network to interconnect the load units and a central unit to perform the task of data processing and network management.

By now, a large number of fieldbuses had been developed for different purposes like home automation, PDA's interconnection, sensor networks, vehicle control and management and industry control. It is possible to specify a control fieldbus for any application, but at first you need to know the market, the costs of the solution proposed and the feasibility of the solution.

Any control fieldbus is based in the Open System Interconnection (OSI) reference model. Simple fieldbuses could be implemented using only the physical and the data link layers, as some actuator/sensor networks. More sophisticated fieldbuses implement all the OSI layers.

In the process of specifying a protocol stack, the main goal of the network (such as power consumption, reliability, network reach) need to be very well stated. In some fieldbuses, this is clearly observed, because all layers of the stack are designed to accomplish the application of the network. One example of this is the brand new PicoRadio, from the University of Berkeley, where the entire stack is being designed focusing in the power consumption, because their main goal is to develop nodes using ultra low power modes to avoid battery replenishments.

Another important question when specifying a control network is the relative cost per node and the installation cost of each node. In some cases, the cost of a node makes impossible the use of a specific fieldbus in a given application. Industry had already perceived this and arranges solutions for this problem. This is the case of the CAN (Controlled Area Network) fieldbus, used mainly for vehicle automation. As the cost of a CAN node will be too high for simple systems in a car (like door control, roof control, steering wheel and steering column, seat control), they designed a fieldbus with reduced cost per node with the capability to share information with the CAN network through gateways, called LIN (Local Interconnection Network).

Concerning the ability to interchange messages between different fieldbuses, it is important to design gateways to translate the protocol stack from one system to another. Almost all new fieldbuses that have been showing up in the market have the capability to translate their messages to the TCP/IP or even UDP/IP protocol stacks. This is very relevant, considering the powerful applications that have been developed for home and industry automation, including the ones that use JAVA to control industry process.

Our objective in the study is to observe interesting features in a set of control fieldbuses, than analyze them and purpose a specification of a control fieldbus with reduced node cost for power management.

II. FEATURES OF A POWER MANAGEMENT FIELDBUS

A power management fieldbus must have specific messages containing all variables related to the power system. This could include information about illumination (luminosity, local presence), power quality (power factor, demand factor, total harmonic distortion, average voltage), power consumption management, maintenance warnings, and so on.

These messages could be subdivided in internal messages and external messages, from the point of view of the consumer. The internal messages will be related to all the information necessary to manage a consumer load unit. The master node of the load unit will provide information to an external network, acting as a gateway capable to interconnect the consumer and the utility sides.

Hierarchically, a power management network could be organized as shown in the Fig. 1:

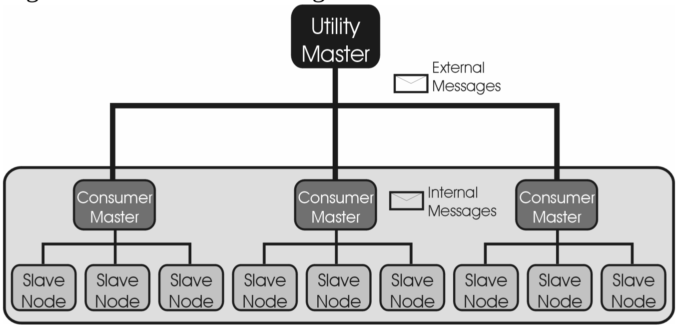

Fig. 1 – Hierarchical View of a Power Management Network

Practical examples of internal messages in a power management fieldbus could be: dim up the lamp, turn on the water heating system, measure the instantaneous voltage level, turn off all loads of a room. Considering the external messages, we could mention preventive maintenance of urban illumination, power quality measurement, power consumption measurement, power demand control and so on.

The consumer master illustrated in the Fig. 1 could provide a TCP/IP or UDP/IP link, so the management of a house or an industry will be done using an application connected to the Internet.

A power management fieldbus that realize all the tasks described will promote a revolution in the areas of power distribution system planning and reliability, and also will rationalize the power consumption.

III. KEY SPECIFICATIONS OF A CONTROL FIELDBUS

A - Network topology

One important feature of a control fieldbus is the network topology, which stands on how the network is organized and how one node can access the communication media. The entire protocol stack, mainly the media access control (MAC) protocol, will rely on the choice of a specific network topology.

The way the master and slaves are wired could vary in too many ways. Basically, we could have a centralized master and all slaves connected to the master (conventional wiring network – see Fig. 2) or a fieldbus-wiring network, were all nodes share the same bus (see Fig. 3).

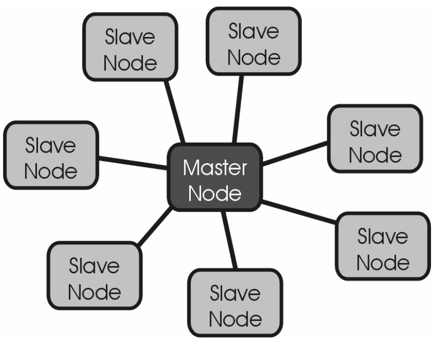

Fig. 2 – Conventional Wiring Network

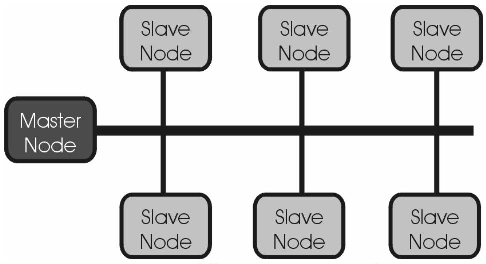

Fig. 3 – Fieldbus Wiring Network

Concerning the control fieldbuses used in the industry nowadays, we could find basically two types of network: single master and multi master.

In a single master network, there is only one master managing the network (see Fig. 4). Generally, the master is responsible for the tasks of data processing, inclusion and exclusion of a node, message filtering and so on. Examples of single master fieldbuses are: Bluetooth (considering a simple Piconet), CeBUS (Consumer Eletronic Bus), LIN, DALI (Digitally Addressable Lighting Interface).

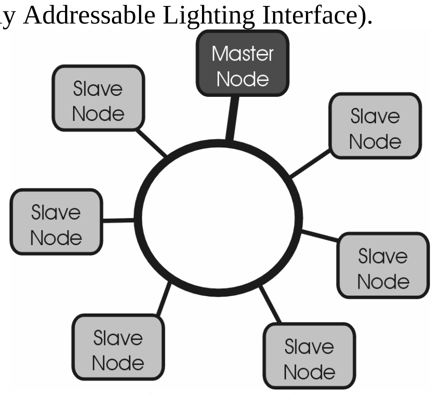

Fig. 4 – Single Master Network

Another used topology is the multi master network. In this arrangement, there are two or more masters sharing the tasks of network management (see Fig. 5). When this type of topology is used, generally there is an arbitration method to determine which master has priority upon the control in a given moment. Examples of multi master fieldbuses are: CAN, LonWorks.

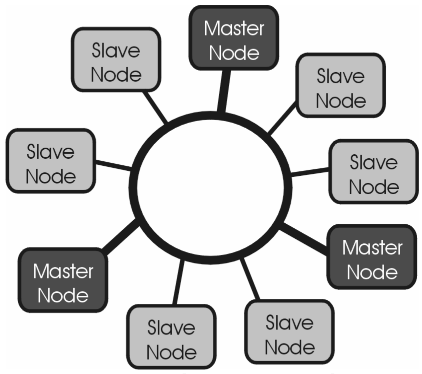

Fig. 5 – Multi Master Network

When designing a control network, it is important to verify the need of a multi master network. This kind of network tends to be more complex, and the costs of a design using this topology increase proportionally with the complexity of the protocol implemented.

For the purposes of power management, we can use both topologies or use a no-master topology. In this topology, a previous configuration in the network is done using a temporary master node, and after the slave nodes change information to each other without the necessity of a master. A single master topology is suitable for home and small industry control, because the tasks involved in the process to be controlled demand short messages and the activity of message exchange is extremely low. This reduces the hardware costs, allowing the design of nodes using microprocessors with low processing capacity and tiny memory space. Thus, if we want to accomplish only an illumination control, the no-master topology is the most suitable, because the need of exchange external messages does not exist. Already in large industries and buildings, the need of the multi masters topology is necessary, due to the size of the installations, facilitating a distributed control of larger reliability.

B– Speed (Bit Rate)

Another key specification of a control fieldbus is how fast the information is passed from one node to another. This is measured by the number of bits transferred per second, generally specified in terms of kilo-bits per second (kbps) or mega-bits per second (Mbps). Some networks use the unit *baud* to specify the speed, but there is a slightly difference between these units. *Baud* derives from Jean Maurice Emile *Baudot*, a 19th century inventor who constructed the first teleprinter (or telegraph) and was used to refer a signaling speed (one morse code dot per second). Nowadays, it refers to a change in the electronic state, and can involve more than just 1 bit of data. Bits per second (or bps) refer to how many bits can be transferred in a second and do not take in account the state of the bits transferred.

Considering the speed (or bit rate), there are some considerations that affect the choice for a specific bit rate to be used in the fieldbus. If the process to be controlled do not demand long messages and a high activity of message transfer to accomplish the tasks of the network, low bit rates are more suitable to be used. This will allow the use of microprocessors with low processing capacity and the transmission media used could be simplified. Higher bit rates will stand for more sophisticated microprocessors and a transmission media with a better performance.

To determine a bit rate to be used in a fieldbus, it is necessary to know the activity of the network, i. e., an approximated number of messages the process need to control all the slaves without lost of information. For example, the activity in sensor networks is very low, so the bit rate for this fieldbus could be reduced. But fieldbuses that are designed to control industrial and vehicle processes, the bit rate need to be higher, like Bluetooth, CAN or Lonworks, that could achieve bit rates in the order of 1 Mbps or even higher.

A network designed to exchange power management messages do not have a high tranfer activity and the message frame use at most 8 bytes, so the bit rate for this kind of fieldbus could be very low, in the order of few kbps.

C– Number of Nodes

The number of nodes of a network is related to the maximum number of addressable devices that could make part in the communication using the common bus.

When using global assignment for a node (physically addressable), the main limitation factor of the number of nodes is the network reach, i. e., how far one message could be send from a node to another without degradation of the information. In the case of using wireless as transmission media, some interesting methods are being used to increase the total number of nodes in a fieldbus. One example of this is the Bluetooth network. In a Bluetooth Piconet, only 7 slaves could participate in the communication, but the specification defines a structure called *scatterenet* to facilitate the communication of nodes from different Piconets. In this configuration, one node serve as bridge for two different Piconets, so the interpiconet communication could be established (see fig. 6).

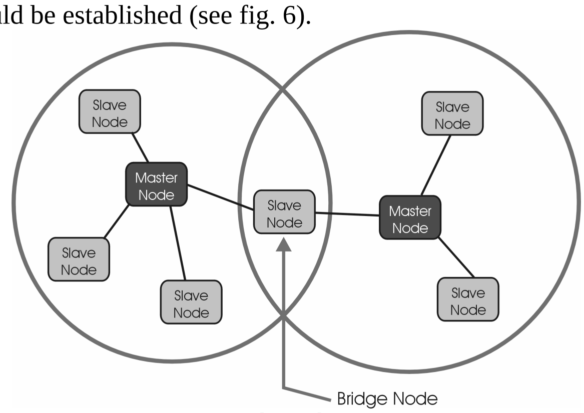

Fig. 6 – Bluetooth Scatternet

In the case of the PicoRadio network, one of the objectives is to deploy a large number of sensors. To accomplish this, sensors may not have global identification (ID). To support a high number of sensors in a small area without using convetional addressing modes, a lot of research had been made to develop protocols with smart routing methods.

Again, the main point to choose the best number of nodes to a network is to focus on the application for which the network will be designed to. There are fieldbuses with large number of nodes, designed specifically for sensor networks (the case of PicoRadio), and fieldbuses with small number of nodes, designed to accomplish simple tasks (as door control in a LIN network).

In the case of power management, the number of nodes for such a network need be the in the order of hundred of nodes, considering the large number of consumption points in a regular application.

The protocol stack must have the capability to provide expansions in the network to support system modifications, for example, in the case of urban illumination. As we know, the illumination of a city is always suffering expansions and modifications.

D– Error Control

There are some specifications that are more suitable to compare the performance of fieldbuses, and one of these is the capacity of the network to handle with errors. Using the right error control scheme for a specific application is essential to improve the network performance. One network that focuses on error control is the CAN fieldbus, which have 5 different errors types not mutually exclusive. The error probability of undetected corrupted messages in CAN fieldbus is less than $4{,}7 \times 10^{-11}$.

There are a lot of methods of error control, but the most used in conventional fieldbuses are forward error correction (FEC) and automatic repeat request (ARQ).

The forward error correction (FEC) technique rely on transmitting data in a encoded form with redundancy, so the receiver is able to detect and correct the error, without requesting a retransmission of the data sended. This technique leads to a higher throughput of the link when the error rate is high.

Automatic Repeat Request (ARQ) method is based on the capability of error detection and no error correction attempt is maded. When a received frame contain an error, the receiver request data to be retransmitted.

Both methods have advantages and disavantages. ARQ is simplier to be implemented but leads to variable delays, which are not acceptable for real-time services. In other hand, FEC leads to a constant throughput of the channel but the complexity of the code implement is much higher than the ARQ method. To overcome their individual drawbacks, the combination of theses two classes of error control schmes have been developed.

For the purposed application of power management, simplier methods like ARQ are more suitable, considering that the cost of a node could be reduced significatively.

E– Addressing Modes

The way one node sends and receives a message is using an addresing scheme to achieve the right destination. Almost all networks have a global assignment for nodes, an specific address to be used in point-to-point communications. Several strategies could be used to facilitate the addressing modes of a network and to promove networks expansions.

Basically, one node could be addressed in two different ways: statically or dynamically. In the first case, one specific address is assigned to a node and this address could not be changed. This type of addressing scheme is used mainly in point-to-point communications, where a message with a specific destination is sent from one node to another. There is also the dynamic scheme of addressing a node, used when mobile nodes acquire an address moving from a region in space where a group of nodes had already settle a communication conversation. One example of fieldbus that uses dynamic addressing scheme is the CeBUS. In CeBUS protocol, there is a *Resource Allocation Function* in the Application Layer that deals with dynamic addressing.

There are other ways to address a message in a fieldbus. One interesting example is the scheme used in CAN and LIN fieldbuses. In these networks, no address is assigned to nodes. Instead of the address field in the message frame, an 11 bits identifier with a description of the data present in the message is broadcasted to all nodes. A message filtering method selects only the relevant messages. A node can stimulate sources to transmit data using a special type of frame, named *remote frame*. This addressing scheme is interesting considering the simplicity to promote networks extensions. CAN networks specify an extended format of the Identifier field, adding 18 bits in the standard 11 bit format.

Some fieldbuses make use of additional addresses to separate nodes in groups. In the CeBUS fieldbus, each node has a *house* address, to divide nodes in houses and groups. Lonworks fieldbus make use of four different types of addresses: physical address, device address, group address and broadcast address. Almost all networks use the address zero to designate a broadcast transmission to all nodes.

For power management, it is interesting to use two types of addressing modes. A group address is interesting to separate nodes in different classes and regions in space. For example, a node could be classified in the illumination group of the hall, or power point of the bedroom, and so on. But if we want to propose a no master topology to an application, for illumination control for example, the no address mode is the most suitable, due to its capacity to work with types of data and not with addresses.

F– Message Destination

A message could be delivered to a node by several ways. It could be sent directly from a source node that specifies the destination address of the message, the so-called point-to-point (P2P) message transfer.

In a point-to-point message transfer, a node assigns a message to another in the same group using the address field of the message frame (see Fig. 7). It could also specify a node from a different group using the group address, used in some fieldbuses.

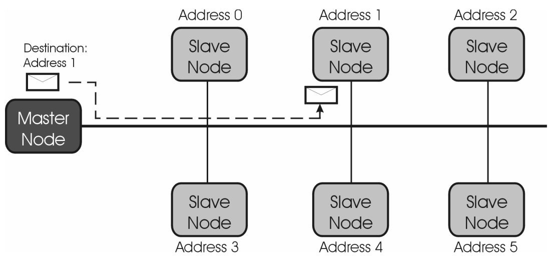

Fig. 7 – Point-to-Point (P2P) message transfer

Another method to deliver messages is using *broadcasting* (see Fig. 8). In this method, a node assigns a message to all nodes in the network, without any message limitation or message filtering.

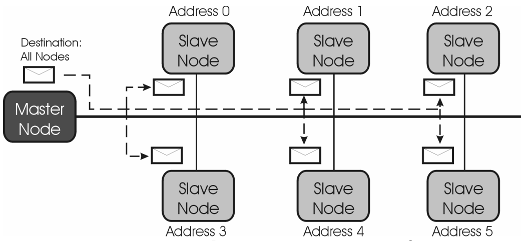

Fig. 8 – Broadcasting Message Transfer

When there is any method to limit the number of recipients of a message, the transfer is called *multicasting* (see Fig. 9).

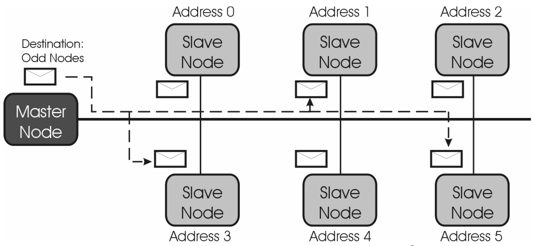

Fig. 9 – Multicasting Message Transfer

There are a lot of hybrid configurations of message transfer being developed nowadays. One interesting variation of broadcasting is the *Direct Diffusion* data dissemination scheme. In this method, a sink node sends out *interest* to all nodes, which contain a *timestamp* field and several *gradient* fields. When the source has data for the interest requested, it sends it through the interest gradient path (see Fig. 10).

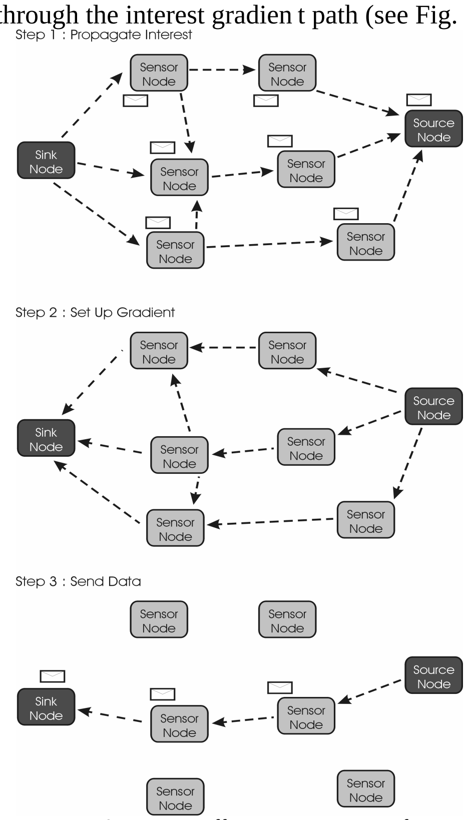

Fig. 10 – Direct Diffusion Message Transfer

A power management fieldbus could use point-to-point message transfer, broadcasting and multicasting. As example, the master could realize a multicast for a specific room, or for all of lamps in a room, or for all lamps in the network.

G – Network Reach

In a control fieldbus, a message could be sent from a node to another that is located in a different room or house. The maximum reach of a network depends on the transmission media used, the communication protocol implement and the application for which the network is designed. In case of using cables to transmit data, important questions to be addressed are the impedance matching used on the bus to minimize line reflections and the grounding technique implemented. Examples of standards for data transmission between nodes in a network are: TIA/EIA-485 (RS485), TIA/EIA-422 (RS422), TIA/EIA-232 (RS232) and TIA/EIA-423 (RS423). Some key specifications of these standards are shown in the table below:

Specifications	RS 485	RS 422	RS 232	RS 423
Mode of Operation	Differential	Differential	Single -Ended	Single -Ended
Maximum Cable Lenght	1200 m	1200 m	15 m	1200 m
Maximum Data Rate	10 Mb/s	10 Mb/s	20 kb/s	100 kb/s
Total number of drivers and receivers	32 drivers 32 receivers	1 driver 10 receivers	1 driver 1 receiver	1 driver 10 receivers

Table 1 – Key specifications of standard data transmission schemes

In the applications that use wireless as communication media, the network depends on the quality of the radio and visibility of the link between the nodes involved in the communication process, from few meters (Bluetooth radio) to thousands of kilometers (Internet radio link).

The network reach is an important question to be addressed for power management networks, because the nodes in such a fieldbus are deployed in wide areas, so it is important to work in the order of thousands of meters.

H – Fault Confinement

When an error occurs in a control fieldbus, the master unit must register the nodes involved in the corrupted message transaction, to prevent future problems in the network.

There are several techniques to prevent network failures and to isolate nodes that harsh the communication channel.

As an example, we could mention the fault confinement mechanism used in the CAN fieldbus. A CAN node, with respect to fault confinement, could be in one of three states: error-active, error-passive or bus-off. Every bus node implements two counters to facilitate fault confinement management: a Transmission Error Count and a Reception Error Count. Initially, all nodes are error -active. The state is changed when a node hits 128 error counts, turning to be an error-passive node.

When an error-passive node hits 128 error counts, it becames a bus-off node, and is not allowed to take part in the communication (the output drivers are switched off).

One question that is essential for a power management fieldbus is the reliability. To assure this, a fault confinement scheme must be able to detect the nodes with failures, notice the problem to all network nodes and avoid sending messages to these nodes. Preventive maintenance in the bus itself and in the sensors, actuators and communication modules could be realized based on these warnings. This is important considering that the application is dealing with power and in this case high quality systems are being required.

I - Transmission Media

In a control fieldbus, the choice for a transmission media is an important issue in the specification process. Generally, the network application defines which transmission media will be used in the communication process. There are networks that define more than one transmission media in the protocol specification. One example is the CeBUS network, which specifies six transmission media in the physical layer of the protocol stack.

The most common media used in the control fieldbuses are: power line (PL), twisted pair (TP), infrared (IR), radio frequency (RF), coaxial cable (CX) and fiber optic (FO). Twisted pair and radio frequency could provide a viable cost/benefit rate for many applications. Fiber optic could be used for applications that demand high transmission rates, with the capability to carry multimedia traffic in an efficient way.

For lighting systems, one interesting choice is the use of power lines to transmit control signaling, reducing the installation cost of the fieldbus. The regulations for power line signaling in the USA and Europe are shown in the table below:

Specifications	USA	Europe - Band A	Europe - Band B
Allowed Band	100 kHz to 450 kHz	9 kHz to 95 kHz	125 kHz to 140 kHz
Modulation Scheme	Spread Spectrum Signalling	Spread Spectrum Signalling	Narrowband Signalling

Table 2 – Regulations for Power Line Signaling

The suitable transmission media for power management are twisted pair and power line. The first option could be considered when the cabling system is already prepared for the fieldbus installation, providing an insulated media to the network. Power line is taken on account when the installation cost of twisted pair is too high and when the environment where the fieldbus will be deployed is not too noisy, so the reliability of the communication could be assured.

IV. CONCLUSION

The purpose of this work is study the main specifications of a set of control fieldbuses and analyze what are the requirements for a control fieldbus for power management.

The market for control fieldbuses is growing each day. It is crucial to know what are the key specifications of a network, so the protocol stack could be designed focusing the application for which the fieldbus is proposed.

A control fieldbus for power management need be costly effective, with a satisfactory payback time. In home and industrial environments, there are a lot of consumption points deployed, so the cost of a node must be low to justify the investments.

Power management is an important issue to be addressed from now to the future. To do so, a dedicated fieldbus with reduced cost and reability will be necessary to use the resources in an efficient and rational way.

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