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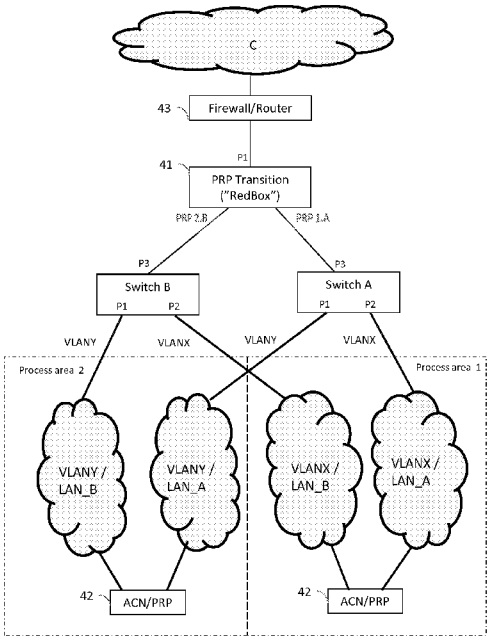

Fig. 4

(57) Abstract: A PRP transition unit (41) has two PRP ports (PRP1.A, PRP2.B) connected to a port (P3) of a first Layer 3 switch (A) and to a port (P3) of a Layer 3 switch (B), respectively. Further, MAC addresses of other two or more ports (P1,P2) of the first switch (A) are duplicated in the second switch (B). The duplicated ports of the switch es (A, B) are connected to two or more virtual or physical local area network (LAN) segments (X,Y) and a respectively.

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REDUNDANCY IN PROCESS CONTROL SYSTEM

FIELD

The present invention relates to arranging redundancy in a process control system.

BACKGROUND

In an industrial process, a highly automatized system is used for ensuring that the process operates in a correct manner. An industrial process, such as a paper making process or a power station process, is very extensive and complex, including many variables. An information system used for controlling an industrial process is responsible for various tasks relating to collecting, distributing, storing and presenting process properties as well as to process control. A process control system typically comprises a large number of work stations that operate independently or controlled by an operator. Such work stations carry out different process control related tasks, such as processing of measurement data and storage of historical data, according to the applications to be executed in the work stations.

Conventionally, process control systems have employed proprietary hardware and software solutions, in which case devices from different manufacturers are unable to communicate with each other. In such a case, it has been necessary to determine proprietary interfaces for applications in order to access data of different devices. Instead of proprietary hardware and software solutions, several standards have been developed to determine open communication interfaces for process control system. An example of such an open standard is OPC (Object Linking and Embedding for Process Control). The OPC provides a set of interfaces, properties and methods based on ActiveX/COM (Component Object Model) technologies to be used for process control applications. A bus solution supporting the OPC standard comprises OPC clients and OPC servers. The OPC servers may communicate with proprietary devices and transfer data to different OPC clients that forward data to applications utilizing the data. The OPC enables a common interface to be provided for the applications so as to enable access to the data of different process control devices.

Process control system and process controllers or nodes are typically provided with redundant network connections to provide real time process data for further computers, such as operator stations in a control room of an

industrial plant. Ethernet, standardized as IEEE 802.3, is widely used for providing network connections for process automation control systems. Network problems may seriously disturb the operation of the process automation system.

EP1483635 discloses a process control system that comprises OPC clients, OPC servers, and devices connected to the OPC servers. The OPC client is provided with at least two parallel logical connections for transferring substantially the same data with one or more OPC server. Property information on parallel data units transferred via different logical connection is checked at the OPC client and compared. The OPC client is provided with predetermined order criteria according to which the parallel data units can be arranged in order of superiority. Parallel data units refer to data units whose payload to be used by an application is exactly or substantially the same. Data units delivered via the logical connection having, according to the predetermined order criteria, the best property information are selected for the use of one or more applications processing the data units.

The functionality of OPC servers serving up to dozens of OPC clients thus plays a crucial role in the information system. In order to ensure the functionality of a system, redundancy of OPC servers may thus be arranged by doubling, meaning that in addition to a primary OPC server, the system is also provided with a secondary OPC server. Such a redundancy arrangement has been disclosed in WO 0 023 857, the solution according to the publication comprising switching over to using the secondary OPC server when the primary OPC server is no longer available. The secondary server may start carrying out the tasks of the primary server without the client devices noticing the change (the logical connection provided for the client device re-mains unchanged although the server device providing the connection changes).

EP1497731 discloses a process control system with a duplicated PROFIBUS-bus (Process Field Bus). The system comprises two control servers, one control server being set to operate as the main (active) control server and the other control server being set to operate as a reserve (passive) control server. The main control server and the reserve control server are connected to each other with a backup bus, which is advantageously duplicated. There are different configurations for a field bus. In one approach, one bus for each field device is formed from each control server. In a second approach, one bus departs from each control server, and these buses are connected to a so-

called Y-switch, via which the control servers connect to a non-duplicated field bus. In this type of a system, only the bus between the control servers is duplicated, but the field bus is not. In the third approach, one bus departs from each control server to a respective hub or repeater. Moreover, there is at least one further hub or repeater to which field devices are connected. The hubs or repeaters may be connected to each other in a ring configuration.

FI20095450 discloses a process control system with control nodes that may, for example, operate as OPC servers for OPC clients in workstations. A redundant Ethernet network and Ethernet switches are applied between the control nodes and the workstations. Each control node is provided by at least two connections, each via a different switch, to provide redundancy for process control related information flows. Thus, each control node may be provided with redundant connections by two or more network interface cards. The switches may belong to different network segments, i.e. redundancy may be provided by arranging connections via different network segments. Primary and secondary network segments may be totally separated or they may be logical segments from a redundant network, which may be entirely mesh-interconnected, for instance. In this case network spanning tree logic should keep the network loop free.

The International Electrotechnical Commission (IEC) standard IEC62439-3 clause 4 specifies the Parallel Redundancy Protocol (PRP) wherein each node is connected in parallel to two local area networks and allows seamless communication in the face of a single network disruption (for instance a cable, driver, switch or controller failure). (IEC 62439-3 Clause 5 specifies the High-availability Seamless Redundancy (HSR) that applies the PRP principle to a ring topology to achieve cost-effective redundancy. Both protocols operate on the same principle. Each node has two ports and sends the same frame simultaneously over two independent connections to the receiving node. The receiving node discards the duplicate frame, if both frames are successfully received.

PRP may implement redundancy in the devices as illustrated in Figure 1A. The principle of operation for PRP is very simple. Each PRP node (called Dual Attached Node, DAN) has two network connections and is attached to two physically independent and uncorrelated networks LAN_A and LAN_B (Local Area Network, LAN). Both interfaces of the DAN have the same MAC address and present the same IP address(es). The networks LAN_A and

LAN_B have no direct connection between them but are completely separated and are assumed to be fail-independent. The networks LAN_A and LAN_B operate in parallel, thus providing a zero-time recovery and allowing checking redundancy. The two networks LAN_A and LAN_B are identical in protocol at the MAC-LLC level, but they can differ in performance and topology. Transmission delays may also be different. Both interfaces of a DAN have the same MAC address and present the same IP address(es). A source DAN transmits its packets as duplicates (with the same MAC address and the same IP address) on both interfaces and hence over both networks LAN_A and LAN_B. In Figure 1B, dotted arrows depict “A” frames transmitted over LAN_A and cross-hatched arrows depict “B” frames transmitted over LAN_B. In an error-free environment a destination DAN receives the same packets on both inter-faces, possibly with a time delay between them. The receiving DAN will use the first of these packets, ignoring the second. There may also be non-PRP nodes, (called SAN or Singly Attached Nodes), the SAN being normal node with only one network interface and are either attached to one network only (and therefore can communicate only with other SANs attached to the same network.

HSR applies the PRP principle of parallel operation to a single network of ring topology, treating the two directions as two virtual LANs. In ring topologies, all devices are connected in a ring. Each device has a neighbour to its left and right. If a connection on one side of the device is broken, network connectivity can still be maintained over the ring via the opposite side of the device. As in PRP, a node has two ports operated in parallel; it is a DANH (Doubly Attached Node with HSR protocol). A simple HSR network consists of doubly attached bridging nodes, each having two ring ports, interconnected by full-duplex links, as shown in the example of Figure 1B for unicast traffic. In other words, each device incorporates a switch that forwards frames from port to port. In Figure 1B, dotted arrows depict “A” frames, cross-hatched arrows depict “B” frames, and grey arrows depict non-HSR frames exchanged between ring and host. Frames A and B circulating in the ring carry the HSR tag inserted by the source, which contains a sequence number. The doublet {source MAC address, sequence number} uniquely identifies copies A and B of the same frame. A destination node of a unicast frame does not forward a frame for which it is the only destination, except for testing. As another example, HSR may also be used with a topology using two independ-

ent networks. HSR nodes can be connected in the same way as PRP nodes to separate LANs.

Figure 2A illustrates an exemplary functional block diagram of a DAN. Each DAN has two ports that operate in parallel and that are attached to the same upper layers of the communication stack through a link redundancy entity (LRE). When upper layer protocol sends a frame, the LRE replicates the frame and sends it through both its ports at nearly the same time. The two frames transit through the two LANs with different delays. Ideally they arrive at the destination node within a small time window. When receiving, a node's LRE forwards the first received frame to its upper layers and discards the duplicate frame. The LRE generates and handles duplicates. This layer presents to its upper layers the same interface as the network adapter of a non-redundant adapter. The LRE has two tasks: handling of duplicates and management of redundancy. To supervise redundancy, the LRE appends to each sent frame a 32-bit redundancy control trailer (RCT) and removes the RCT at reception. A DAN has the same MAC address for both ports, and only one set of IP addresses. This makes redundancy transparent to the upper layers. Figure 2B illustrates an Ethernet frame provided with an RCT inserted after the payload "LSDU" so that the RCT remains transparent to normal network traffic. The RCT may contain a sequence counter "SeqNr", a LAN indicator "Lanid" and a size field "LSDU size" inserted after the payload "LSDU".

Sometimes operator may wish to split large switched networks, which are large broadcast domains. Traditional LAN segmentation adds routers to the network to split a broadcast domain. Devices in a LAN segment are connected to a respective router, and communication between different LAN segments occurs via routers. A VLAN (Virtual LAN) is a Layer 2 method of creating independent logical networks within a single physical network. Hosts in the same physical LANbehave as if they are connected to different LAN segments For example, as illustrated in Figure 3, a local area network may be implemented with a single physical network 31 (LAN A) that may be logically divided into sub networks (VLANX, VLANY) using a VLAN technology. VLAN technology is defined in IEEE Standard 802.3q, for example. Without VLANs, a switch treats all interfaces (i.e. Network Interface Controllers, NICs) on the switch as being in the same broadcast domain, i.e. all connected devices are in the same LAN A. With port-based VLANs, a Layer 3 switch 32 can put some interfaces into one broadcast domain and some into another. Thus, instead of

all ports on a switch 32 forming a single broadcast domain, the switch separates them into multiple broadcast domains (logical Ethernet segments, VLANs), based on configuration. All devices connected to a given port (e.g. port 1 and port 2 in Figure 3) automatically become members of the VLAN (e.g. VLANX and VLANY, respectively) to which that port was assigned. Each interface or port of a switch must have one unique MAC address. MAC addresses are most often assigned by the manufacturer of a network interface controller (NIC) and are stored in its hardware, such as the card's read-only memory or some other firmware mechanism. VLANs limit the broadcast domain, improve security and performance and are ideal for separating industrial automation systems internally and separating them from information technology systems. An additional benefit of VLAN technology is that operator can add security features to control traffic from VLAN to another. The logical division to subnetworks may be based on which device groups they need to communicate with regularly, e.g. devices in different parts of a process may be divided in different VLANs. This means that devices in one VLAN will not be able to communicate directly with devices in another VLAN, such that unwanted traffic in each VLAN, or group of devices, is eliminated. An Ethernet router 33 can be introduced which will allow data to be routed to and from other networks 34.

SUMMARY OF THE INVENTION

An aspect of the present invention is a system enabling PRP network in a local area network having subnetworks. The objects of the invention are achieved by a redundant gateway system and a method according to attached independent claims. The preferred embodiments of the invention are disclosed in attached dependent claims.

An aspect of the invention is a system for providing a parallel redundancy protocol (PRP) network, comprising

a parallel redundancy protocol (PRP) transition unit having a first and second PRP interfaces,

a first network switch having a first interface, a second interface, and a third interface connected to the first PRP interface of the PRP transition unit,

a second network switch having a first interface, a second interface, and a third interface a third interface connected to the second PRP interface of the PRP transition unit,

the first interfaces of said first network switch and said second network switch are configured to have a common first MAC address or a common set of MAC addresses, and

the second interfaces of said first network switch and_said second network switch are configured to have a common second MAC address or set of MAC addresses.

In an embodiment, the first interfaces and said second interfaces of said network switches are configured to interface to a first virtual or physical local area network segment and a second virtual or physical local area network segment, respectively.

In an embodiment,

the system, having said first interfaces of said network switches connected to said first LAN segment, is configured to form a first pair of PRP networks within said first LAN segment by sending and receiving duplicated data packets with same addresses to and from at least one dual attached node connected to said pair of PRP networks in said first LAN segment, and

the system, having said second interfaces of said network switches connected to said second LAN segment, is configured to form a second pair of PRP networks within said second LAN segment of a local area network by sending and receiving duplicated data packets with same addresses to and from at least one dual attached node connected to said pair of PRP networks in said second LAN segment.

In an embodiment, said first and second LAN segments comprise a first virtual LAN and a second virtual LAN.

In an embodiment, said first virtual LAN and said second virtual LAN configured in a single physical LAN.

In an embodiment, said first and second physical LAN segments comprise a first physical LAN of a linear topology and a second physical LAN of a linear topology.

In an embodiment, said PRP transition unit comprises a PRP adapter, particularly a Redundancy Box.

In an embodiment, said first and second network switches comprise layer 3 switches.

In an embodiment, said first and second LAN segments comprise layer 2 switches.

In an embodiment, the first and second LAN segments are config-

ured to provide separated process control networks for different parts of a process plant.

BRIEF DESCRIPTION OF DRAWINGS

Some embodiments of the present invention are described below, by way of example only, with reference to the accompanying drawings, in which

Figure 1A is a block diagram illustrating an example of Parallel Redundancy Protocol (PRP) network topology;

Figure 1B is a block diagram illustrating an example of High-availability Seamless Redundancy (HSR) network topology;

Figure 2A is a block diagram illustrating exemplary functional blocks diagram of a Doubly Attached Node (DAN);

Figure 2B illustrates an Ethernet frame provided with a Redundancy Control Trailer (RCT) inserted after the payload;

Figure 3 is a schematic block diagram illustrating a virtual LAN concept;

Figure 4 is a hypothetical network topology implementing a PRP VLAN concept; and

Figure 5 is a hypothetical network topology implementing a PRP using linear LAN segments.

EXEMPLARY EMBODIMENTS

Figure 4 illustrates an exemplary arrangement according an aspect of the invention for implementing a parallel redundancy protocol (PRP) in a local area network (LAN) using virtual LAN (VLAN) technology.

In the exemplary embodiment shown in Figure 4, a A PRP transition unit 41, such as a RedBox, has two PRP network interfaces or ports PRP1.A and PRP2.B connected to a port or interface P3 of a Layer 3 switch A and to a port or interface P3 of a Layer 3 switch B, respectively. From the PRP transition unit 41 point of view the port PRP1.A connected to LAN_A and the port is PRP2.B connected to LAN_B of a PRP network, effectively in a same way as

the RedBox in the example illustrated in Figure 1A. The configuration of the networks LAN_A and LAN_B is transparent to the PRP transition unit 41. Further, ports or interfaces P1 of the switches A and B are configured to have a common first MAC address or a common set of MAC addresses, and ports or interfaces P2 of the switches A and B are configured to have a common second MAC address or a common set of MAC addresses. Such configuration is against the established principles that MAC addresses shall be unique (MAC addresses are typically hardwired in devices). However, in combination with the PRP transition 41 such identical configuration of the pair of switches A and B will enable new types of PRP network implementations as will be described in more detail below. In other words, each PRP interface MAC address of the Layer 3 switch A is duplicated in the Layer 3 switch B. Thereby, a VLAN support is provided to the PRP technology, and the network to which the ports P3 of the switches A and B are connected, e.g. the PRP transition unit 41, will see the underlaying network correctly.

Let us first have few words about network switching and routing generally. A network switch is a hardware device that joins multiple computers or hosts together within a local area network (LAN). Traditional network switches operate at Layer 2 of the OSI model, also referred to as the Data Link layer. Media access control (MAC) data communication protocol is a sublayer of the data link layer. The MAC sublayer provides addressing and channel access control mechanisms that make it possible for several terminals or network nodes to communicate within a multiple access network that incorporates a shared medium, e.g. Ethernet, at Layer 1 of the OSI model. A Layer 2 switch relies on the MAC addresses to determine the source and destination of a packet. A Layer 2 switch may learn MAC addresses automatically, building a table which can be used to selectively forward packets based on MAC addresses. For example, if a switch receives packets from MAC address X on Port 1 it then knows that packets destined for MAC address X can simply be forwarded out of that port rather than having to try each available port in turn. A Layer 3 switch operates at Layer 3 of the OSI model A and can support the same routing protocols as network routers do. Internet Protocol (IP) is the most

common Layer 3 protocol. A Layer 3 switch can have a IP routing table for lookups and it can form a broadcast domain. On the other hand, the layer 3 switch still have Layer 2 features such as spanning tree and trunking, and it acts like a layer 2 switch when it is connecting devices that are on the same network. Other intelligence commonly found in Layer 3 switches, includes the ability to logically segment a network into two or more Virtual LANs (VLANs). The Layer 3 switch can efficiently do inter-VLAN routing or to do internal routing between multiple broadcast domains or segments. Examples of Layer 3 switches include SwitchBlade 4000 Series Layer 3 modular switches from Allied Telesis.

In the exemplary embodiment shown in Figure 4, the switches A and B are VLAN aware switches, and the switches A and B are configured to split a physical LAN network, preferably a process automation network, into two separated virtual LAN segments VLAN X and VLAN Y that may correspond to process areas 1 and 2 in an automation system. In other words, separated process control networks for different parts of a process plant may be provided using VLAN technology .More specifically, the switch A configures a first half of the VLANY via the port P1 and the switch B configures a second half of the VLANY via the port P1. Similarly, the switch A configures a first half of the VLANX via the port P2 and the switch B configures a second half of the VLANX via the port P2. Layer 2 network switches may be used in the VLANs X and Y. Effectively, as the switch A provides the LAN_A and the switch B provides the LAN_B to the PRP transition unit 41, a PRP topology is provided in a single physical network split using VLAN technology. More specifically, the VLANX and VLANY each effectively comprise two separated, parallel operating, fail-independent and uncorrelated networks LAN_A and LAN_B. Each Dual Attached Node (DAN) 42, referred to as a PRP node ACN/PRP herein, is connected in parallel to both networks LAN_A and LAN_B. The ACN/PRP 42 has two ports that share the same MAC address and present the same IP address(es) per port. One port of the ACN/PRP 42 is connected to LAN_A and the other port is connected to LAN_B. Different ACN/PRPs 42 naturally have different unique addresses. Although two VLANs are illustrated in the example,

any number of VLANs may be created. Similarly, although one ACN/PRPs 42 in each VLAN is illustrated in the example, any number of ACN/PRPs may be connected.

As illustrated in Figure 4, the PRP Transition unit 41 typically has also an interface P1 towards a conventional network or network C, possibly through a firewall or router 43. The PRP Transition unit 41 may be any entity, such as RedBox (Redundancy Box) in accordance with the IEC62439-3 clause 4, which behaves like a DAN to connect one network interface P1 to both LANs LAN_A and LAN. Example of a commercially available device suitable to be used as the transition unit 41 is the RSP switch Hirschmann RSP25 from Belden Inc . As discussed above, MAC address duplicates are used in the redundant communication between the PRP Transition unit 41 and the PRP node ACN/PRP 42. Basically the PRP Transition unit 41 receives duplicate packets from the LAN_A and LAN_B of the PRP network via the interface PRP1.A and PRP2.B respectively, and removes one of the duplicates and sends the other duplicate packet via the interface P1. Similarly in the reverse direction, the PRP Transition unit 41 receives packets via the interface P1, duplicates them and sends the duplicate packets over LAN_A and LAN_B to the PRP node 42. Similarly, the PRP node 42 sends the same frame simultaneously over two independent connections to the receiving node duplicate packets over LAN_A and LAN_B to the PRP Transition unit 41, and upon receiving duplicate packets from the LAN_A and LAN_B the PRP node 42 removes one of the duplicates and transfers the other duplicate packet to upper protocol layers. The mechanism of duplicate generation and duplicate rejection is thus carried out at PRP capable entities and completely transparent to devices or networks connected to the interface P1 such as the network C. Thereby, a situation wherein the same MAC address is registered at two different ports of a switch in other networks, which is an intolerable state, is avoided. Such a situation, also referred to as a “mac-flap” error would be encountered without the arrangement according to an aspect of the invention.

Figure 5 illustrates another exemplary arrangement according an aspect of the invention for implementing a parallel redundancy protocol (PRP)

in a local area network (LAN) split without using virtual LAN (VLAN) technology. In the example of Figure 5, a combination of a PRP transition unit 41, such as a RedBox, and two identically configured Layer 3 switches A and B may be provided. Same names and references symbols in Figures 4 and 5 may refer to same structures or functionalities as described unless noted otherwise. From the PRP transition unit 41 point of view the port PRP1A connected to LAN_A and the port is PRP2B connected to LAN_B of a PRP network, effectively in a same way as the RedBox in the example illustrated in Figure 1A. The configuration of the networks LAN_A and LAN_B is transparent to the PRP transition unit 41. Further, ports or interfaces P1 of the switches A and B are configured to have a common first MAC address or a common set of MAC addresses, and ports or interfaces P2 of the switches A and B are configured to have a common second MAC address or a common set of MAC addresses. In other words, each PRP interface MAC address of the Layer 3 switch A is duplicated in the Layer 3 switch B, and the network to which the ports P3 of the switches A and B are connected, e.g. the PRP transition unit 41, will see the underlying network correctly.

However, in the exemplary embodiment shown in Figure 5, the switches A and B are configured to split a physical LAN network, preferably a process automation network, into separated linear LAN segments or branches X and Y that may correspond to two or more process areas in an automation system. In other words, separated process control networks for different parts of a process plant may be provided using linear LAN topology. More specifically, the switch A configures a first half of the linear LAN Y (that may comprise a plurality of Layer 2 switches Y/LAN_A) via the port P1 and a common media, and the switch B configures a second half of the linear LAN Y (that may comprise a plurality of Layer 2 switches Y/LAN_B) via the port P1and a common media. Similarly, the switch A configures a first half of the linear LAN X (that may comprise a plurality of Layer 2 switches X/LAN_A) via the port P2 and a common media, and the switch B configures a second half of the linear LANX (that may comprise a plurality of Layer 2 switches X/LAN_B) via the port P2 and a common media. In a linear LAN network topology, the switches nodes

are connected to a common media or bus or in a daisy chain by a linear sequence of buses (although physical topology inside the split process areas can be any).

Effectively, as the switch A provides the LAN_A and the switch B provides the LAN_B to the PRP transition unit 41, a PRP topology is provided in a single physical network split using parallel linear LAN branches X and Y. More specifically, the LANX and LANY each effectively comprise two separated, parallel operating, fail-independent and uncorrelated networks LAN_A and LAN_B. Each Dual Attached Node (DAN) 42, referred to as a PRP node ACN/PRP herein, is connected in parallel to both networks LAN_A and LAN_B. The ACN/PRP 42 has two ports that share the same MAC address and present the same IP address(es) per port. More specifically, one port of the ACN/PRP 42 is connected to a port in the switch X/LAN_A or Y/LAN_A and the other port is connected to a port in the switch X/LAN_B or Y/LAN_B. Although a specific number of linear LANs is illustrated in the example, any number of linear LANs may be employed.

The network topology according to exemplary embodiments can be applied to any process control system. The process control system may be arranged to control any industrial process or the like. The industrial processes may include, but are not limited to, processes in a processing industry, such as pulp and paper, oil refining, petrochemical and chemical industries, or processes in power plants, etc.

There are various architectures for a process control system. For example, the process control system may be a Distributed Control System (DCS). One example of such a decentralized control system is Metso DNA (DNA, Dynamic Network of Applications) delivered by Metso. A central processing unit(s) of a process control system controlling the productive activity of an entire factory, such as a paper mill, is (are) often called a control room, which may be composed of one or more control room computer(s)/programs and process control computer(s)/programs as well as databases. A process control system may comprise a control room bus/network that may interconnect user interface components and control computers of the room. A control

room bus/network may be a local area network, for example, based on the standard Ethernet technology. A process bus/network may, in turn, interconnect process control components, such as control nodes ACN 42 with each other. The process bus/network may be implemented as a redundant PRP network similar to that shown in Figure 4 or 5. Control nodes ACN 42 may also be connected to the control room network, allowing communication between control nodes ACN42 and user interfaces, for example. The term "control node" refers generally to a computer-based apparatus, which may be used for process control purposes, such as a process controller, backup, display server, etc. Example of a commercially available device suitable to be used as the ACN 42 is a Metso DNA ACN process controller with variety of operating roles (PRP DAN mode). The control node ACN 42 may be connected to one or more input/output I/O units of field devices for arranging field device control. The term "field device" refers generally to devices of the process being monitored and/or controlled. Typically there is a high number of process devices (field devices), such as actuators, valves, pumps and sensors, in a plant area (field). The process control system may be provided with a firewall/router environment, such 43 shown in Figures 4 and 5, to effectively isolate the process control network from other network C, such as a normal office network of the plant, referred to as a mill network herein. The separation ensures that potential problems in the office network will not affect the control room bus and vice versa. Direct Internet access from the automation network is prohibited.

The accompanying drawings and the description pertaining to them are only intended to illustrate the present invention. The above-illustrated embodiments may be combined in various ways. Different variations and modifications to the invention will be apparent to those skilled in the art, without departing from the scope of the invention defined in the appended claims. Different features may thus be omitted, modified or replaced by equivalents.

CLAIMS

1. A system for providing a parallel redundancy protocol (PRP) network, comprising

a parallel redundancy protocol (PRP) transition unit having a first and second PRP interfaces,

a first network switch (A) having a first interface, a second interface, and a third interface connected to the first PRP interface of the PRP transition unit,

a second network switch (B) having a first interface, a second interface, and a third interface a third interface connected to the second PRP interface of the PRP transition unit,

the first interfaces of said first network switch (A) and said second network switch (B) are configured to have a common first MAC address or a common set of MAC addresses, and

the second interfaces of said first network switch (A) and said second network switch (B) are configured to have a common second MAC address or set of MAC addresses.

2. A system as claimed in claim 1, wherein the first interfaces and said second interfaces of said network switches (A, B) are configured to interface to a first virtual or physical local area network (LAN) segment (X) and a second virtual or physical local area network (LAN) segment (Y), respectively.

3. A system as claimed in claim 2, wherein

the system, having said first interfaces of said network switches connected to said first LAN segment, is configured to form a first pair of PRP networks (LAN_A, LAN_B) within said first LAN segment (X) by sending and receiving duplicated data packets with same addresses to and from at least one dual attached node (CAN) connected to said pair of PRP networks (LAN_A, LAN_B) in said first LAN segment, and

the system, having said second interfaces of said network switches connected to said second LAN segment, is configured to form a second pair of PRP networks (LAN_A, LAN_B) within said second LAN segment (Y) of a local area network (LAN) by sending and receiving duplicated data packets with same addresses to and from at least one dual attached node (CAN) connected to said pair of PRP networks (LAN_A, LAN_B) in said second LAN segment (Y).

4. A system as claimed in claim 2 or 3, wherein said first and second LAN segments comprise a first virtual LAN and a second virtual LAN.

5. A system as claimed in claim 4, wherein said first virtual LAN and said second virtual LAN configured in a single physical LAN.

6. A system according to claim 2 or 3, wherein said first and second physical LAN segments comprise a first physical LAN of a linear topology and a second physical LAN of a linear topology.

7. A system as claimed in in any one of claims 1-6, wherein said PRP transition unit comprises a PRP adapter, particularly a Redundancy Box.

8. A system as claimed in in any one of claims 1-7, wherein said first and second network switches comprise layer 3 switches.

9. A system as claimed in in any one of claims 1-8, wherein said first and second LAN segments comprise layer 2 switches.

10. A system as claimed in any one of claims 1-9, wherein the first and second LAN segments are configured to provide separated process control networks for different parts of a process plant.

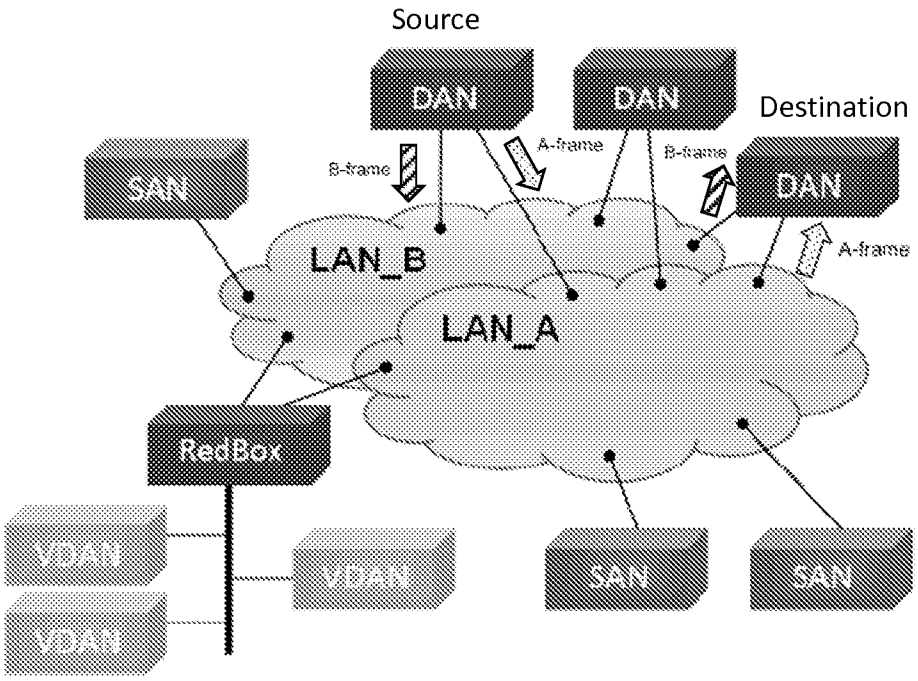
Source
DAN
DAN
Destination
SAN
B-frame
A-frame
B-frame
DAN
A-frame
LAN_B
LAN_A
RedBox
VDAN
VDAN
VDAN
SAN
SAN

Fig. 1A

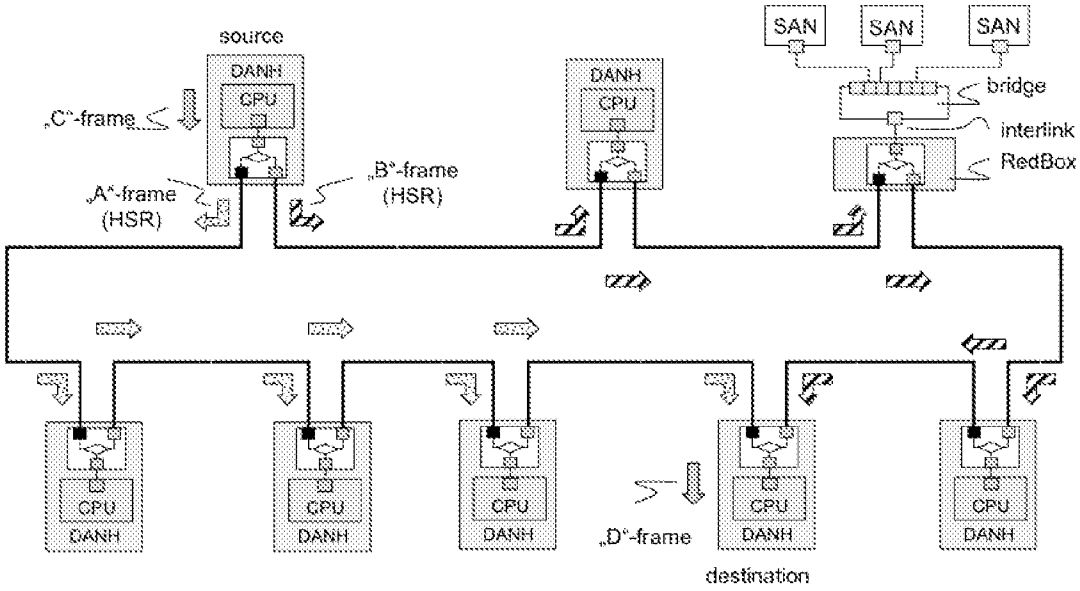
source
DANH
CPU
„C"-frame
„A"-frame
(HSR)
„B"-frame
(HSR)
DANH
CPU
SAN
SAN
SAN
bridge
interlink
RedBox
CPU
DANH
CPU
DANH
CPU
DANH
„D"-frame
CPU
DANH
destination
CPU
DANH

Fig. 1B

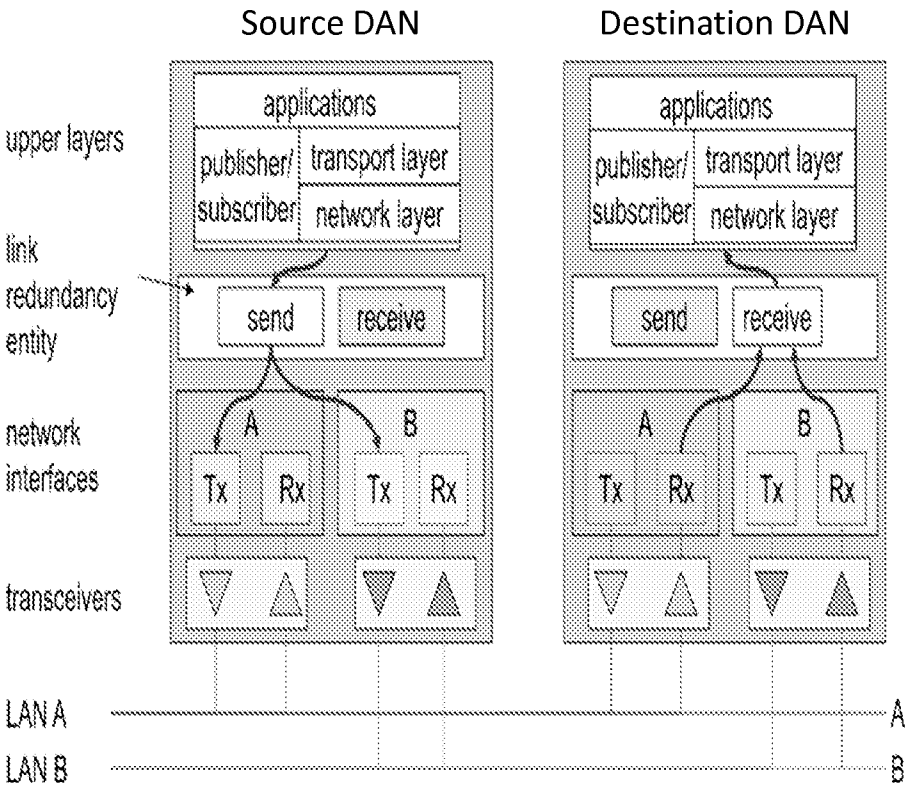
Source DAN
Destination DAN
upper layers
link redundancy entity
network interfaces
transceivers
applications
publisher/ subscriber
transport layer
network layer
send
receive
A
B
Tx
Rx
LAN A
LAN B

Fig. 2A

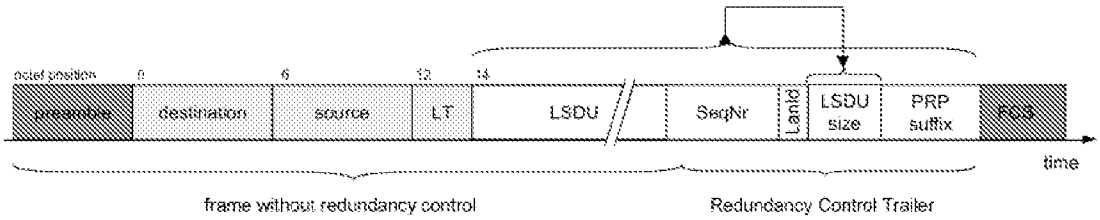
octet position
0
6
12
14
preamble
destination
source
LT
LSDU
SeqNr
LanId
LSDU size
PRP suffix
FCS
time
frame without redundancy control
Redundancy Control Trailer

Fig. 2B

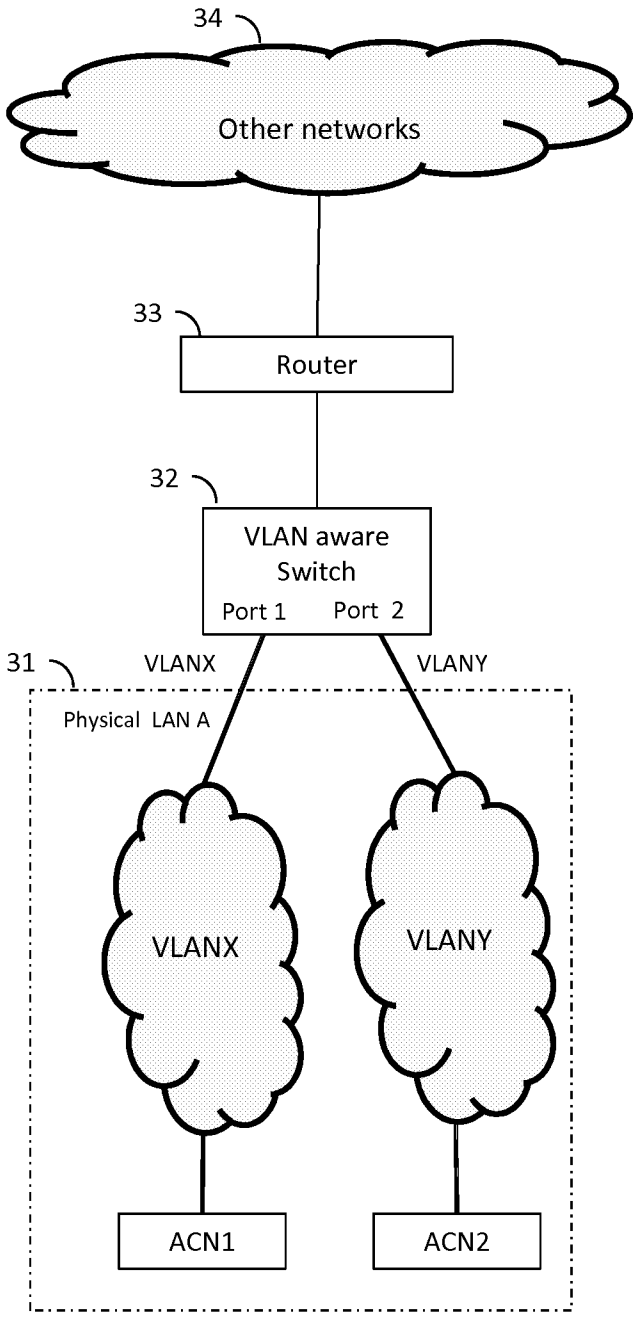
34
Other networks
33
Router
32
VLAN aware
Switch
Port 1
Port 2
31
VLANX
VLANY
Physical LAN A
VLANX
VLANY
ACN1
ACN2

Fig. 3

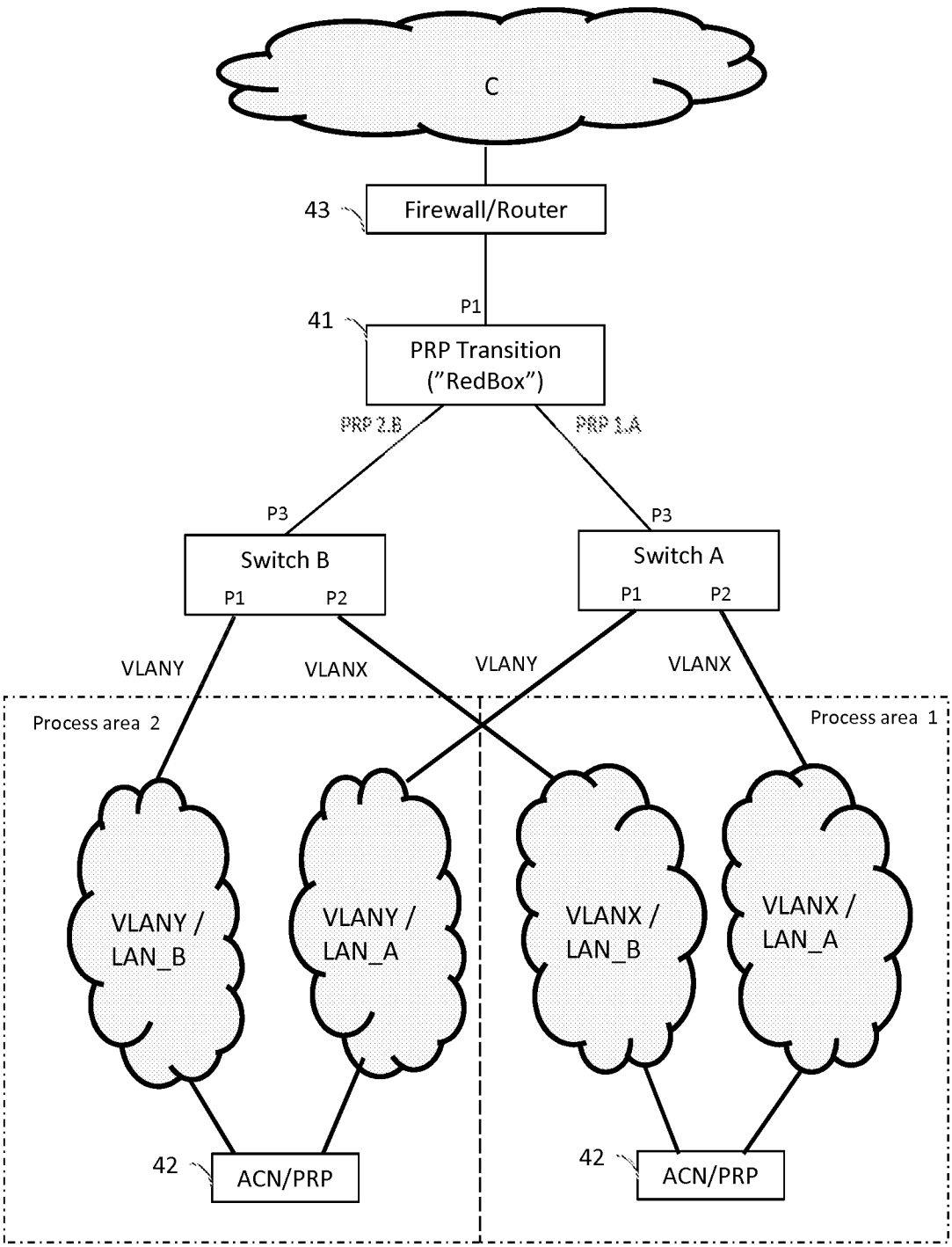
C
43
Firewall/Router
P1
41
PRP Transition
("RedBox")
PRP 2.B
PRP 1.A
P3
P3
Switch B
P1
P2
Switch A
P1
P2
VLANY
VLANX
VLANY
VLANX
Process area 2
Process area 1
VLANY /
LAN_B
VLANY /
LAN_A
VLANX /
LAN_B
VLANX /
LAN_A
42
ACN/PRP
42
ACN/PRP

Fig. 4

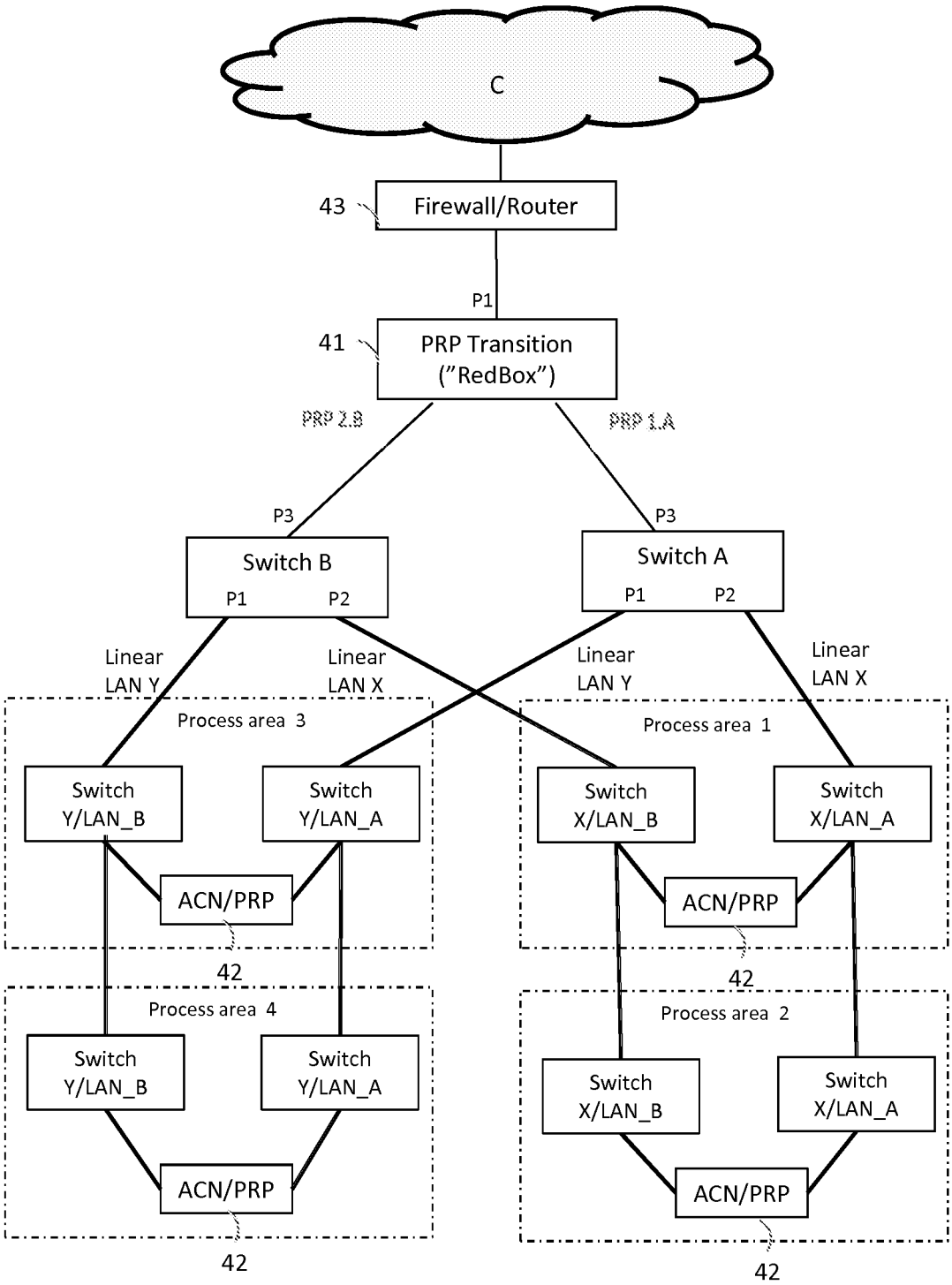
C
43
Firewall/Router
P1
41
PRP Transition
("RedBox")
PRP 2.B
PRP 1.A
P3
P3
Switch B
P1
P2
Switch A
P1
P2
Linear
LAN Y
Linear
LAN X
Linear
LAN Y
Linear
LAN X
Process area 3
Process area 1
Switch
Y/LAN_B
Switch
Y/LAN_A
Switch
X/LAN_B
Switch
X/LAN_A
ACN/PRP
ACN/PRP
42
42
Process area 4
Process area 2
Switch
Y/LAN_B
Switch
Y/LAN_A
Switch
X/LAN_B
Switch
X/LAN_A
ACN/PRP
ACN/PRP
42
42

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2014/051007

A. **CLASSIFICATION OF SUBJECT MATTER**

See extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: G05B, G06F, H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

FI, SE, NO, DK

Electronic data base consulted during the international search (name of data base, and, where practicable, search terms used)

EPO-Internal, WPIAP, XPIPCOM, XPETSI, NPL, INSPEC, XPI3E, XPESP, XPIETF, XPIEE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6751191 B1 (KANEKAR BHUSHAN MANGESH [US] et al.) 15 June 2004 (15.06.2004) column 1 lines 7-12, column 8 lines 41-66 and figures 3, 7, 8 and 14A, see also: column 8 line 67 – column 16 line 47 and figures 9, 10, 11A, 11B, 12A, 12B, 12C, 12D, 13A, 13B and 14B	1-10
A	Krammer et al. 'A Software-Based Redundancy Concept For Building Automation Networks'. IECON 2013 - 39th Annual Conference of the IEEE Industrial Electronics Society. 10th November 2013. Pages 5702-5709.	1-10
A	FLATT et al. 'Mapping of PRP/HSR Redundancy Protocols onto a Configurable FPGA/CPU Based Architecture'. International Conference on Embedded Computer Systems: Architectures, Modeling, and Simulation (SAMOS). 15th July 2013. Pages 121-128.	1-10

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
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"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
03 June 2015 (03.06.2015)	22 June 2015 (22.06.2015)

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INTERNATIONAL SEARCH REPORT
Information on Patent Family Members

International application No.
PCT/FI2014/051007

Patent document cited in search report	Publication date	Patent family members(s)	Publication date
US 6751191 B1	15/06/2004	US 7006431 B1	28/02/2006
		US 8077604 B1	13/12/2011
		US 2012076048 A1	29/03/2012

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2014/051007

CLASSIFICATION OF SUBJECT MATTER

IPC
H04L 29/12 (2006.01)
G06F 11/16 (2006.01)
H04L 1/22 (2006.01)