

Actuation of execution units

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The present invention relates to a method for actuating execution units and to a correspondingly set-up system arrangement. Moreover, a communication node is proposed which is suitable for use in the method or in the system arrangement. The present invention further relates to a computer program comprising control commands which implement the proposed method or operate the proposed system arrangement.

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DE 10 2014 003 066 A1 discloses bus subscribers in a bus network and teaches dynamic addressing therefor.

DE 10 2018 007 141 A1 discloses a system arrangement for error-tolerant, electromagnetically acceptable actuation of a plurality of execution units.

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DE 10 2016 125 290 A1 disclose a chained two-wire bus consisting of two single-wire data buses.

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WO 2017/162 323 A1 discloses an efficient control arrangement and a control method in which sequentially arranged execution units are actuated by means of a command unit.

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WO 2018/103 880 A1 discloses a compact LED arrangement, which can be used generically but, as a result of the compact construction, is advantageous in particular for use in a vehicle.

In conventional methods, a plurality of options are known for addressing control units connected in series. Generic approaches exist, which may be

disadvantageous in specific application scenarios, as well as highly specialised approaches, which are no longer usable generically. For example, the CAN bus is known, which was developed in relation to cable harnesses and is intended to implement networking of control devices in particular.

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In general, the complexity of the CAN protocol is much greater than for ISELED (registered trade mark) and thus more expensive. However, the greatest drawback of CAN and LIN is that because of the bus architecture they do not offer a natural (automatic) addressing option. In these cases, the address has to be configured. For ISELED (execution units), and also for segmented ISELED (line driver unit and execution units), there is a physically predetermined string, resulting in the option of assigning addresses automatically.

15 From the prior art, various execution units are known, which typically operate as a slave or a client and thus receive commands from a superordinate instance, typically referred to as a master. The execution units subsequently implement these commands. For this purpose, the prior art discloses various architectures or topologies in which corresponding execution units along with the control units thereof are to be arranged.

25 However, in this context the prior art has the problem that different requirements are set depending on the application scenario, and thus overall it has to be weighed up whether an energy-efficient method having high error susceptibility is to be provided, or a method which takes up more energy but is more error-proof as a result. Moreover, the dimensions of the provided place of use of an architecture of this type are to be taken into account. Some arrangements are not suitable for large-area use, and can therefore only be implemented on individual circuit boards. By contrast, other architectures

can be installed over a large area over several metres, and thus have to meet completely different requirements from system arrangements on individual circuit boards.

- 5 In individual application scenarios there are very specific requirements, which cannot be satisfied using generic network architectures. As a result, it is necessary to propose special protocols, network architectures and methods which precisely meet the needs of the application scenario. One special field of application is the automotive field, where work is cost-efficient, in other
10 words involves low technical outlay, and moreover reliable network architectures are required. The reason why the reliability of the network architectures is so important is that automobiles are subject to longer maintenance intervals, and as a result the customer would not tolerate a failure of this type. Moreover, safety-critical functions are often being provided, making
15 failure safety essential.

Thus, among other things, in the prior art it is disadvantageous that network components may be provided which do not address the application scenario because individual components are too large-scale and potentially imple-
20 ment logic which is potentially not used. Moreover, there is a need for network architectures or components which are particularly efficient and which can also be produced with low technical outlay.

Failure safety is provided in that, among other things, individual compo-
25 nents can be segmented in such a way that if an individual segment fails no further segments are affected. Overall, the components should be equipped as simply as possible so as to be able to work energy-efficiently and additionally to be able to function in an error-proof manner. Overall, as little energy as possible should be taken up, since not only does this have costs in

terms of the energy itself, but there is also a risk of emitted radiation, and moreover development of heat is disadvantageous.

5 A further problem in the prior art is that often a particular network architecture prevents efficient implementation of a protocol. Thus, from the prior art, segmentations of network topology are known in which protocols of this type are optimised for series arrangements. Translating protocols which are optimised for series arrangements is typically complex and susceptible to error. It is thus advantageous to provide a method or a system arrangement
10 which makes error-proof segmentation possible and additionally provides an efficient protocol, in such a way that the network architecture can work in an efficient, error-proof manner. Overall, it is always required for network protocols and network architectures to work compatibly with existing components.

15 Accordingly, an object of the present invention is to propose an improved method for actuating execution units which runs efficiently and in particular combines the advantages of both a series chain of execution units and a segmentation of execution units. Moreover, an object of the present invention is
20 to propose a correspondingly set-up system arrangement, as well as a communication node which can be used both in the proposed method and in the proposed system arrangement. Moreover, an object of the present invention is to provide a computer program product comprising control commands which implement the proposed method or operate the system arrangement.

25 The object is achieved by the features of claim 1. Further advantageous configurations are proposed in the dependent claims.

Accordingly, a method for actuating execution units is proposed, comprising providing a physical network of series sub-chains of execution units, the individual sub-chains being addressed in series and, if an execution unit fails, merely the rest of the sub-chain failing, each sub-chain initially having exactly one upstream communication node connected upstream, and the communication nodes of the sub-chains being chained together in series in such a way that there is a communication chain of upstream communication nodes, individual communication nodes being switched to be passive in such a way that the rest of the communication chain persists, the communication nodes each having at least one input interface and at least one output interface and the at least one input interface and the at least one output interface being explicitly lockable, sequentially checking each of the sub-chains by means of a query to the respectively upstream communication node of the sub-chain in question, which node assigns a unique identifier to each execution unit of the sub-chain in such a way that each execution unit in the network is assigned a unique identifier, and addressing at least one execution unit, by means of the upstream communication node, with a command generated by a control unit upstream from the communication chain.

The execution units may take the form of components which are each independent, for example LEDs or sensors. This should merely be understood as an example, and all possible components may be used, for example network components such as a switch. The execution units receive control commands from a control unit, which may take the form of a microcontroller.

According to the invention, initiation of the physical network is provided in such a way that the individual execution units receive an identifier and an address. As a result, the network itself is initially unknown, and in preparatory method steps the network is checked in such a way that components,

specifically execution units, are identified and receive an identifier. The identifier serves to address the associated execution unit, in such a way that the control unit can address each individual execution unit selectively.

5 In a preparatory method step, a physical network of series chains of execution units is provided. This means that there is at least one sub-chain which is constructed in series, and as a result the execution units are coupled together in series. This sub-chain initially has a communication node. Thus, according to the invention, it is provided that a sub-chain consists of at least one communication node. Preferably, but optionally, further execution units are coupled to this communication node. As a result, a first execution unit is communicatively coupled to a communication node. At least one further execution unit may be coupled to this first execution unit. Thus, an execution unit typically has at least two interfaces, one interface unit being coupled either to the communication node or to the preceding execution unit, and a second interface unit to a following execution unit. There is thus a sequence from a communication node, to which at least one further execution unit is connected in series. Exceptionally, it is also possible for merely the communication node to be present.

20 Since there are a plurality of sub-chains, there are also a plurality of communication nodes, and it is also possible in turn to interconnect the plurality of communication nodes. Thus, figuratively speaking, the sub-chains are present horizontally, as is also shown in the accompanying drawings. This results in for example a two-dimensional network, in which the execution units extend horizontally and the communication nodes extend vertically.

Thus, indirectly, all execution units are coupled to one another, in such a way that a communication node is connected upstream from each sub-chain of

execution units and these upstream communication nodes are in turn coupled to one another in series.

5 The individual units may be coupled in different ways. Thus, it is preferably provided that the individual segments or sub-chains are arranged on a circuit board comprising a corresponding bus and the communication nodes may be coupled to one another using a wired connection. This is merely to be understood as an example and not as being definitive.

10 The communication starts from a control unit upstream from the communication chain. The communication nodes as a whole thus form a communication chain, at the start of which the control unit is located. As a result, the control unit can communicate indirectly with the execution units, a communication node being connected upstream from each sub-chain. The control
15 unit thus primarily communicates with the communication nodes, which subsequently each pass on the control commands to the connected sub-chain.

Since it is initially not known which components are located in the physical network, each of the sub-chains is checked sequentially, in each case by
20 means of a query to the associated upstream communication node. As a result, the control unit outputs a command which causes each communication node to check the sub-chain thereof, and subsequently corresponding identifiers are returned. It is thus advantageous that the control unit communicates with a first communication node, which subsequently checks how many or
25 which execution units are arranged in the sub-chain in question. When this has been detected, the identifiers are returned to the control units, and this may generally also take place at a later point in time. As a result, when the first sub-chain has been checked, it is provided that, by means of a command to the second communication node, this communication node is caused to

check the sub-chain thereof, and as a result generates identifiers which for example consecutively number the individual execution units.

5 This takes place sequentially and iteratively, in such a way that all communication nodes check the arranged sub-chains, and issue a unique identifier in each case for this purpose. The unique identifier is therefore available to the communication node, which thus has information as to which units are arranged in the sub-chain. Since all communication nodes pass on the identifiers thereof to the control unit, the control unit then has information concerning all available communication nodes along with attached execution units.

10 Once the individual identifiers of the execution units are known, at least one execution unit may be addressed, in such a way that it is addressed by the control unit indirectly via the communication node using the identifier. Thus, ultimately, each identifier of the execution units is known to the control unit, and the control unit can thus instruct the corresponding communication node, the chain of which includes the execution unit to be actuated, to bring about precisely this actuation. As a result, the control unit outputs a command which is conveyed indirectly via the communication node to the execution unit in question. A command may be a command which performs a read operation or a write operation. Thus, for example, as a command a sensor may be read out or else an LED has a corresponding colour value or brightness intensity conveyed thereto. Moreover, it is generally possible to read out status information from the execution units. This information is subsequently in turn conveyed indirectly via the communication nodes to the control unit.

According to the invention, it is particularly advantageous that the individual sub-chains can be addressed in series and an efficient protocol is thus cre-

- ated. In this context, it is also possible, however, to segment the individual execution units in such a way that there is not a single sub-chain. There are thus a plurality of segments or sub-chains overall. Failure safety is thus provided so that if a member of a chain fails the whole of the rest of the chain
- 5 does not fail, but rather merely the rest of the sub-chain fails. Thus, according to the invention, it is particularly advantageous that the individual execution units can be controlled sequentially or in series but there may still be segmentation in hardware.
- 10 Moreover, it is particularly advantageous that the individual communication nodes can be switched to be passive, in such a way that signals are merely passed through these communication nodes. Thus, an individual sub-chain can fail, but the functionality of the further sub-chains is not impaired.
- 15 In one aspect of the present invention, the actuation comprises a read operation and/or a write operation. This has the advantage that either the command from the control unit may cause a sensor value or status to be read out from the execution unit or a write operation takes place in such a way that a value can be communicated to the execution unit. This value may be a colour
- 20 intensity or a brightness. In general, a combination of both operations is also possible.

In a further aspect of the present invention, the unambiguous identifier takes the form of an address, a numbering and/or a name. This has the advantage

25 that the individual execution units can be uniquely identified and subsequently a unique identifier, by means of which the execution unit can selectively initiate the execution unit, can be communicated to the control unit. In general, the identifier is also a general name, in such a way that for example human-readable source code is produced.

In a further aspect of the present invention, when the execution unit is addressed for reading there is only communication with the sub-chain which includes the addressed execution unit. This has the advantage that further
5 sub-chains can be masked and thus merely series communication takes place, in such a way that the control unit communicates with the execution unit indirectly via a communication node. The preceding communication nodes are thus connected through, and the output interface to following communication nodes is blocked. As a result, efficient addressing of execution units
10 can be implemented. In particular, segmentation has an advantage because there is no need to address all execution units in series until the execution unit to be actuated is reached, but rather execution units from preceding sub-chains can be skipped.

15 In a further aspect of the present invention, the communication nodes each have at least one input interface and at least one output interface. This has the advantage that the communication nodes typically have three interfaces, which take the form of coupled interfaces and can process both input signals and output signals. The interfaces are each described in greater detail with
20 reference to the accompanying drawings. The interfaces are generally for data communication, it also being advantageous to block individual interfaces.

In a further aspect of the present invention, the at least one input interface and the at least one output interface may be explicitly blocked. This has the
25 advantage that efficient implementation takes place and interfaces can be blocked in such a way that further communication is not possible. This ensures that execution units which are not addressed also do not have to be further taken into account in the communication. Thus, typically only the

sub-chain which includes the addressed execution unit is addressed. Further sub-chains are switched off in this manner by blocking interfaces.

5 In a further aspect of the present invention, the at least one input interface and the at least one output interface may be blocked by the control unit and/or the associated communication node. This has the advantage that different protocols can be implemented and it can be decided both centrally and in a decentralised manner which interfaces are to be blocked.

10 In a further aspect of the present invention, the at least one input interface and the at least one output interface can be blocked as a function of a provided identifier. This has the advantage that it can be determined from the identifier which execution unit is to be addressed, and subsequently only the sub-chain which includes the execution unit is switched to be active. Thus, the
15 preceding communication nodes are switched to be passive, in other words to connect through, and all further communication nodes are blocked. Thus, in the communication path, only one sub-chain is addressed, and all further sub-chains are masked in the communication. As a result, the proposed method is particularly efficient.

20 In a further aspect of the present invention, the unique identifiers are conveyed to the control unit sequentially. This has the advantage that the identifiers are each returned, this taking place for example in such a way that the last execution unit in the network conveys the identifier back to the communication node indirectly via the preceding execution units, and the communication node subsequently conveys the identifier to the control unit. This then
25 takes place using the penultimate execution unit, until the sub-chain in question has been worked through. Subsequently, the identifier of the last execution unit in the penultimate sub-chain is passed back.

In a further aspect of the present invention, to each communication node, the identifiers from the sub-chain from which the communication node is upstream are conveyed. This has the advantage that the communication node
5 has information from all execution units of the sub-chain thereof available. Each communication node thus knows the execution units from which it is upstream.

In a further aspect of the present invention, individual communication nodes
10 are switched to be passive in such a way that the rest of the communication chain persists. This has the advantage that individual communication nodes and thus sub-chains can be masked out in communication. Thus, from the control unit, there is only communication with the sub-chain which includes the addressed execution unit. As a result, signals are merely passed through
15 or looped through by preceding communication nodes unchanged, in other words unprocessed.

In a further aspect of the present invention, the sub-chains segment the entirety of the execution units. This has the advantage that not all execution
20 units have to be connected in series, but rather individual segments can be created, and efficient protocolling still takes place by way of processing of individual sub-chains. Overall, the failure safety is increased as a result, since if one execution unit fails not all further execution units connected in series fail, but rather the execution units are segmented in such a way that merely
25 all further execution units within the segment fail.

The object is also achieved by a communication node which is set up for use in the proposed method or in the proposed system arrangement.

The object is also achieved by a system arrangement for actuating execution units, comprising a physical network of series sub-chains of execution units, the individual sub-chains being addressable in series and being set up in such a way that if an execution unit fails merely the rest of the sub-chain fails, each sub-chain initially having exactly one communication node connected upstream, and the communication nodes of the sub-chains being chained together in series in such a way that there is a communication chain of upstream communication nodes, individual communication nodes being switchable to be passive in such a way that the rest of the communication chain persists, the communication nodes each having at least one input interface and at least one output interface and the at least one input interface and the at least one output interface being explicitly lockable, the communication nodes set up for sequentially checking each of the sub-chains by means of a query to the respectively upstream communication node of the sub-chain in question, which node is set up to assign a unique identifier to each execution unit of the sub-chain in such a way that each execution unit in the network is assigned a unique identifier, and a control unit set up for addressing at least one execution unit, by means of the upstream communication node, with a command generated by a control unit upstream from the communication chain.

The object is also achieved by a computer program product comprising control commands which carry out the method or operate the proposed system arrangement when the control commands are executed on a computer.

According to the invention, it is particularly advantageous that the system arrangement provides structural features which functionally correspond to the method steps. Further, method steps are proposed which can also be structurally imitated by the system arrangement in terms of the correspond-

ing functionality. Thus, the method is for operating the system arrangement and the system arrangement can carry out the proposed method.

Further advantages, features and details of the invention will be apparent
5 from the following description, in which aspects of the invention are described in detail with reference to the drawings. The features mentioned in the claims and in the description may, each individually per se or in any desired combination, be essential to the invention. Likewise, the aforementioned features and those set out hereinafter may be used each in their own
10 right or in a plurality in any desired combinations. Functionally similar or identical components are in some cases provided with the same reference signs. The terms "left", "right", "top" and "bottom" used in describing the embodiments relate to the drawings in an orientation with a normally readable drawing title and normally readable reference signs. The embodiments
15 shown and described are not to be understood as definitive, but rather are of an exemplary nature for explaining the invention. The detailed description is for the information of a person skilled in the art, and so known circuits, structures and details are not shown or explained in detail in the description so as not to impede understanding of the present description. Further advantageous configurations are described in greater detail with reference to the
20 accompanying drawings, in which:

Fig. 1 shows an aspect of the communication node according to the invention and in particular the interface units thereof;

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Fig. 2 is a state transition diagram showing states of the communication node, method or system arrangement according to the invention;

Fig. 3 is a schematic block diagram showing an aspect of the proposed system arrangement and a communication progression in accordance with the proposed method and in particular execution of the "INIT" command;

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Fig. 4 is a further schematic block diagram showing an aspect of the proposed system arrangement and a communication progression in accordance with the proposed method and in particular execution of the "PING1" command;

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Fig. 5 is a further schematic block diagram showing an aspect of the proposed system arrangement and a communication progression in accordance with the proposed method and in particular execution of the "PING2" command;

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Fig. 6 is a further schematic block diagram showing an aspect of the proposed system arrangement and a communication progression in accordance with the proposed method and in particular execution of the "WRITE" command;

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Fig. 7 is a further schematic block diagram showing an aspect of the proposed system arrangement and a communication progression in accordance with the proposed method and in particular execution of the "REG_READ" command;

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Fig. 8 is a further schematic block diagram showing an aspect of the proposed system arrangement and a communication progression in accordance with the proposed method and in particular execution of the "CHAIN_READ 1" command;

Fig. 9 is a further schematic block diagram showing an aspect of the proposed system arrangement and a communication progression in accordance with the proposed method and in particular execution of the "CHAIN_READ 2" command;

Fig. 10 is a further schematic block diagram showing an aspect of the proposed system arrangement and a communication progression in accordance with the proposed method and in particular execution of the "INTERRUPT 1" command;

Fig. 11 is a further schematic block diagram showing an aspect of the proposed system arrangement and a communication progression in accordance with the proposed method and in particular execution of the "INTERRUPT 2" command;

Fig. 12 is a schematic flow chart showing an aspect of the method according to the invention for actuating execution units.

Fig. 1 shows a communication node ICN and shows in particular the corresponding interfaces. Thus, a communication node typically has a master interface unit MA_PORT, illustrated at the top in this case, a client interface unit CL_PORT, illustrated on the right in this case, and a slave interface unit SL_PORT, illustrated at the bottom in this case. The orientation of the communication node corresponds to the orientation as shown in the further drawings. Figuratively speaking, the communication chain is arranged vertically and the sub-chains are arranged horizontally. The shown communication node thus communicates upwards either with further communication nodes or with the control unit. To the right, the communication node com-

municates with a first execution unit. The execution unit optionally communicates with further execution units. Downwards, the shown communication node optionally communicates with further communication nodes.

However, the end of the communication chain may also be reached, in such a way that no more communication nodes are connected.

Fig. 2 is a state transition diagram, and shows in particular two states at the top and two at the bottom. The top left state is the state where the network is shown uninitialised. The arrows within the individual states show the direction of communication which is involved in this case. Thus, for initialisation, starting from the control unit at the top, a control command is conveyed to the right into the sub-chains. The values are ultimately passed back upwards, in such a way that the identifiers are known in the control unit.

The individual execution units communicate via the communication node. At top right, a state is shown which exhibits complete initialisation. The upper arrow signals that write operations and read operations can take place iteratively, since ultimately all execution units are known. The initialisation takes place in such a way that a query is sent to the individual components. Further, at bottom left a ping, in other words a query message, is waited for. If a component is queried, it reports back, and if a time window is exceeded, a timeout occurs. Thus, all components can be queried iteratively. At bottom right, it is illustrated that reading of the vertical chain is waited for until all communication nodes return the gathered identifiers.

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Fig. 3 shows the physical network, the control unit taking the form of a microcontroller, which is illustrated at the top in this case. Moreover, the communication nodes ICN are present on the left. ICN stands for ISELED communication network (registered trade mark), by way of example. The com-

munication nodes are thus arranged vertically, and the execution units are arranged horizontally. Herein, an execution unit is, by way of example, an LED or a sensor. Alternatively, an execution unit may also take the form of a switch.

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Moreover, Fig. 3 clarifies, by way of the individual numbers, how the identifiers are initialised. Thus, an identifier 1 is assigned to the first communication node and then an identifier 2 is assigned to the second communication node. Thereupon, the connected sub-chain is provided with identifiers in such a way that the first LED receives an identifier 3, the second LED receives an identifier 4 and the third LED receives an identifier 5. Subsequently, these identifiers are returned to the communication node 2. Thereupon, identifiers are issued in the next sub-chain, which is illustrated at the bottom in this case. Thus, the upstream communication node receives the identifier 6 and a sensor connected thereto receives the identifier 7. Subsequently, this identifier is returned and passed on via the communication node 6, 2 and 1 to the control unit. Subsequently, further identifiers are issued, in such a way that the next sub-chain, to which a switch 9 is coupled as well as a sensor 10 and an LED 11, starts with a communication node 8.

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This is demonstrated below using pseudo source code, including English terms which are familiar to a person skilled in the art in this form and which he would also use in this manner.

25

- Reset:
 - STATE = "uninitialized"
- wait for INIT command:
 - all commands are discarded, except INIT
- INIT command detected at MA_Port:

- generate new INIT command and send to CL_Port
 - wait for INIT sequence to complete at clients:
 - set Address Registers and status_client.init
 - generate new INIT command with addr = last_client_addr+1
 - 5 ○ send INIT on SL_Port
 - if last in chain:
 - generate INIT answers* and send on MA_Port
 - STATE = "initialized"
 - else :
 - 10 ○ wait for INIT answers on SL_Port:
 - pass on to MA_Port
 - when complete:
 - generate INIT answers* and send on MA_Port
 - STATE = "initialized"
 - 15
- * INIT answer includes:
client address + status_client.init
own address + config.is_icn
- 20 In Fig. 3 and the following figures, components are based on example components. In particular, the switch 9 may take the form of a switch, an actuator, an interrupter and/or a scanner. The arrow from the components 9, 10 and 11 to the ICN 8 may be implemented using an interrupter, or at least one interrupter may be used in the communication. The same applies to the
- 25 communication from the component 7 to the ICN 6. Arrows may always also be understood bidirectionally, even if this is not illustrated, since the direction of communication may also be reversed in direction during communication or during at least one further communication.

Fig. 4 shows a ping process in which a corresponding message is conveyed to the associated upper interface unit of the communication node. Subsequently, these messages are conveyed to the sub-chain and in turn returned from the sub-chain to the communication node. Subsequently, they are passed on to the associated communication node following below, which then in turn checks the sub-chain thereof. Finally, the result is passed on upwards to the control unit.

- STATE = "initialized"
- 10 ○ NEXT_IS_PING command detected at MA_Port:
 - STATE = "wait for ping"
 - when command received at MA_Port:
 - pass on to CL_Port, but not to SL_Port
 - when answer received at CL_Port:
 - 15 ○ pass on to SL_Port
 - when answer received at SL_Port:
 - pass on to MA_Port

Fig. 5 shows further progression of the process, and illustrates the communication process by way of the arrows. The following source code illustrates this wait for an answer, and in particular error handling is also demonstrated.

- STATE = "wait for ping"
- 25 ○ wait for PING command at MA_Port:
 - pass on to CL_Port, but not to SL_Port
 - wait for PING sequence to complete at clients
 - save answer in last_client_answer register
 - if last in chain:

- forward client answer to MA_Port
- STATE = "initialized"
- else:
 - if answer = last_client_addr:
 - 5 ○ send PING on SL_Port
 - wait for answer on SL_Port
 - forward answer to MA_Port
 - STATE = "initialized"
 - else: //client chain is not intact!
 - 10 ○ send PING on SL_Port
 - wait for answer on SL_Port
 - overwrite answer with value of
last_client_answer Register
 - send to MA_Port
 - 15 ○ STATE = "initialized"

Fig. 6 shows a write process, in which a corresponding query to the communication node ICN is carried over from above and said node subsequently passes on the command both to the right and to the further unit below. If a response is received from the sub-chain by a control unit, this is passed on upwards, and if a communication node receives a response from below, this is likewise passed on to the control unit.

- STATE = "initialized"
- 25 ○ when command received at MA_Port:
 - pass on to SL_Port and CL_Port
- when answer received at CL_Port:
 - pass on to MA_Port
- when answer received at SL_Port:

- pass on to MA_Port

Fig. 7 shows reading out a registration, a command being received from above at the associated communication node and then being passed on
5 downwards and to the right. If an answer comes from the right, it is passed on upwards, and an answer from below is likewise passed on upwards.

- STATE = "initialized"
- when command received at MA_Port:
10 ○ pass on to SL_Port and CL_Port
- when answer received at CL_Port:
○ pass on to MA_Port
- when answer received at SL_Port:
○ pass on to MA_Port

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Fig. 8 shows reading out the communication chain, in other words the individual communication nodes. In general, the state of the network is initialised, it also being possible that not all control units have been initialised yet and that it is therefore necessary to wait until the initialised process is terminated. This scenario distinction is shown by the following source code text.
20

- STATE = "initialized"
- NEXT_IS_CHAIN command detected at MA_Port, with ICN address as parameter of command:
25 ○ if parameter = own_address:
○ STATE = "initialized"
- else:
○ STATE = "wait for chain_read"
- when command received at MA_Port:

- pass on to SL_Port, but not CL_Port
 - when answer received at CL_Port:
 - ignore
 - when answer received at SL_Port:
- 5 ○ pass on to MA_Port

Fig. 9 shows further progression of reading out the communication chain. Here, all execution units are known, and the identifiers are finally passed on to the control unit. The state of the network can thus qualify as initialised.

- 10
- STATE = "wait for chain_read"
 - wait for CHAIN_READ command at MA_Port
 - pass on command to SL_Port, but not CL_Port
 - STATE = "initialized"

- 15
- Fig. 10 shows an interruption which is passed on to the individual sub-chains. If, in the present example, the last sub-chain is reached, the status of the associated execution units is read out, and these are returned further upwards to the control unit. If the status of the execution units is present, the
- 20 corresponding parameter is deleted again.

- STATE = "initialized"
 - when Open Collector pulled down:
 - status_client.interrupt = 1
- 25 ○ IR_READ command detected at MA_Port
- pass on to SL_Port and CL_Port
 - if last in chain:
 - send Client Status Register as answer to MA_Port
 - status_client.interrupt = 0

- else:
 - wait for answers on SL_Port
 - pass on to MA_Port
 - when complete:
 - 5 ○ send Client Status Register as answer to MA_Port
 - status_client.interrupt = 0

Fig. 11 shows the further progression of the interruption process, and shows in particular that the interruption is ultimately eliminated.

- 10 ○ STATE = "initialized"
- when Open Collector pulled down:
 - status_client.interrupt = 1
- IR_READ command detected at MA_Port
 - 15 ○ pass on to SL_Port and CL_Port
 - if last in chain:
 - send Client Status Register as answer to MA_Port
 - status_client.interrupt = 0
 - else:
 - 20 ○ wait for answers on SL_Port
 - pass on to MA_Port
 - when complete:
 - send Client Status Register as answer to MA_Port
 - status_client.interrupt = 0
- 25 μ C:
 - If IR=1 at ICN:
 - Read interrupt registers of all corresponding clients that support interrupt

Fig. 12 is a schematic flow chart showing a method for actuating execution units, comprising providing 100 a physical network of series sub-chains of execution units, the individual sub-chains being addressed in series and, if an
5 execution unit fails, merely the rest of the sub-chain failing, each sub-chain initially having exactly one communication node ICN connected upstream, and the communication nodes ICN of the sub-chains being chained together in series in such a way that there is a communication chain of upstream communication nodes ICN, individual communication nodes ICN being
10 switched to be passive in such a way that the rest of the communication chain persists, the communication nodes ICN each having at least one input interface and at least one output interface and the at least one input interface and the at least one output interface being explicitly lockable, sequentially checking 101 each of the sub-chains by means of a query to the respectively
15 upstream communication node ICN of the sub-chain in question, which node assigns 102 a unique identifier to each execution unit of the sub-chain in such a way that each execution unit in the network is assigned a unique identifier, and addressing 103 at least one execution unit, by means of the upstream communication node ICN, with a command generated by a control unit up-
20 stream from the communication chain.

In this context, a person skilled in the art will recognise that the described method steps may be carried out iteratively and/or in a different order. In addition, individual method steps may have sub-steps.

CLAIMS

1. A method for actuating execution units, comprising:
 - (a) providing a physical network of a series of sub-chains connected in series,
 - (i) wherein each sub-chain includes an execution unit;
 - (ii) wherein the execution unit of each sub-chain is assigned a unique identifier;
 - (iii) wherein, if the execution unit of an individual sub-chain fails, the execution units of the sub-chains connected in series to the individual sub-chain do not fail also as a result of the failure of the execution unit of the individual sub-chain;
 - (iv) wherein each sub-chain includes exactly one up-stream communication node (ICN);
 - (v) wherein the communication nodes (ICN) of the sub-chains are chained together in series and establish a communication chain of upstream communication nodes (ICN);
 - (vi) wherein the communication node (ICN) of each sub-chain passes through signals received, such that the rest of the communication chain persists if the sub-chain fails;
 - (vii) wherein the communication nodes (ICN) include at least one input interface and at least one output interface; and
 - (viii) wherein the at least one input interface and the at least one output interface of the communication node (ICN) of each sub-chain are selectably lockable, as selected by the unique identifier of the execution unit of the sub-chain; and
 - (b) sequentially checking each of the sub-chains by means of a query to the respectively upstream communication node (ICN) of the sub-chain in question, wherein the unique identifier of the execution unit of each sub-chain is assigned by the upstream communication node (ICN) with a command generated by a control unit upstream from the communication chain.
2. The method according to claim 1, characterised in that the actuation comprises a read operation and/or a write operation
3. The method according to either claim 1 or claim 2, characterised in that the unique identifier takes the form of an address, a numbering and/or a name.

4. The method according to any of the preceding claims, characterised in that the at least one input interface and the at least one output interface can be blocked by the control unit and/or the associated communication node (ICN).
5. The method according to any of the preceding claims, characterised in that the at least one input interface and the at least one output interface can be blocked as a function of a provided identifier.
6. The method according to any of the preceding claims, characterised in that the individual identifiers are conveyed to the control unit sequentially.
7. The method according to any of the preceding claims, characterised in that, to each communication node (ICN), the identifiers from the sub-chain from which the communication node (ICN) is upstream are conveyed.
8. The method according to any of the preceding claims, characterised in that the sub-chains segment the entirety of the execution units.
9. A system arrangement for actuating execution units, the system comprising a physical network of a series of sub-chains connected in series,
 - (a) wherein each sub-chain includes an execution unit;
 - (b) wherein the execution unit of each sub-chain is assigned a unique identifier;
 - (c) wherein, if the execution unit of an individual sub-chain fails, the execution units of the sub-chains connected in series to the individual sub-chain do not fail also as a result of the failure of the execution unit of the individual sub-chain;
 - (d) wherein each sub-chain includes exactly one up-stream communication node (ICN);
 - (e) wherein the communication nodes (ICN) of the sub-chains are chained together in series and establish a communication chain of upstream communication nodes (ICN);
 - (f) wherein the communication node (ICN) of each sub-chain passes through signals received, such that the rest of the communication chain persists if the sub-chain fails;
 - (g) wherein the communication nodes (ICN) include at least one input interface and at least one output interface;

- (h) wherein the at least one input interface and the at least one output interface of the communication node (ICN) of each sub-chain are selectably lockable, as selected by the unique identifier of the execution unit of the sub-chain;
- (i) wherein the system is configured to sequentially check each of the sub-chains by means of a query to the respectively upstream communication node (ICN) of the sub-chain in question; and
- (j) wherein the unique identifier of the execution unit of each sub-chain is assigned by the upstream communication node (ICN) with a command generated by a control unit upstream from the communication chain.

10. A computer program product comprising control commands which carry out the method according to any of claims 1 to 8 when they are executed on a computer.