LOCAL AREA NETWORK OF SERIAL INTELLIGENT CELLS

FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to local area networks and, more particularly, to local area network topologies based on serial intelligent cells.

Bus Topology

Most prior art local area networks (LAN) use a bus topology as shown by example in Figure 1. A communication medium **102** is based on two conductors (usually twisted pair or coaxial cable), to which data terminal equipment (DTE) units **104, 106, 108, 110,** and **112** are connected, via respective network adapters **114, 116, 118, 120,** and **122.** A network adapter can be stand-alone or housed within the respective DTE.

This prior art bus topology suffers from the following drawbacks:

1. From the point of view of data communication, the medium can vary significantly from one installation to another, and hence proper adaptation to the medium cannot always be obtained.
2. The bus topology is not optimal for communication, and hence:
   a) the maximum length of the medium is limited;
   b) the maximum number of units which may be connected to the bus is limited;
   c) complex circuitry is involved in the transceiver in the network adapter;
   d) the data rate is limited.
3. Terminators are usually required at the ends of the medium, thus complicating the installation.
4. Only one DTE can transmit at any given time on the bus, and all other are restricted to be listeners.
5. Complex arbitration techniques are needed to determine which DTE is able to transmit on the bus.
6. In case of short circuit in the bus, the whole bus malfunctions, and it is hard to locate the short circuit.

7. Addresses should be associated independently with any network adapter, and this is difficult to attain with bus topology.

Star Topology

A number of prior art network devices and interconnections summarized below utilize star topology.

The multiplexer is a common item of equipment used in communication, both for local area networks and wide-area networks (WAN's). It is used in order to provide access to a data communications backbone, or in order to allow sharing of bandwidth between multiple stations. As shown in Figure 2, one side of a multiplexer **202** is usually connected to a single high data rate connection **204** ("highway"), but several such connections can also be used. The other side of multiplexer **202** has multiple low data rate connections **206, 208, 210, 212,** and **214**. The cllipsis ... indicates that additional connections can be made. Each low data rate connection uses part of the bandwidth offered by the high data rate connection. These low data rate connections can be of the same type or different types, and can have different or identical data rates. The multiplexing technique most commonly used is time-domain multiplexing (TDM). However, frequency-domain multiplexing (FDM) is also used.

A popular multiplexer in use is the voice multiplexer, shown in Figure 3. A pulse-code modulation (PCM) bus **304** handling 2.048 megabits per second, containing 30 channels of 64 kilobits per second is connected to one side of a PABX/PBX **302**, and up to 30 telephone interfaces **308, 312,** and **316** are connected to the other side via connections **306, 310,** and **314**. The ellipsis ... indicates that additional connections can be made. In this configuration, each channel in the PCM bus can be switched or be permanently dedicated to a specific telephone line. An example of such system is disclosed in US Patent No. 3,924,077 to Blakeslee.

Similarly a small ,private branch exchange (PABX/PBX), as shown in Figure 4, is widely used (usually in an office or business environment) where several outside lines **403, 404,** and **405** are connected to one side of a PABX/PBX **402**, and multiple telephones **408, 412,** and **416** are connected to the other side via lines **406, 410,** and **414**, respectively. The ellipsis ... indicates that additional connections can be made. The PABX/PBX connects an outside line to a requesting or requested telephone, and allows connection between telephones in the premises.

In the configurations described above, star topology is used in order to connect to the units to the multiplexer, which functions as the network hub. The disadvantages of star topology include the following:

1. A connection between each unit and the network hub is required, and the wiring required for this connection can involve a lengthy run. Thus, when adding new unit, an additional, possibly lengthy, connection between the new unit and the network hub must be added.
2. No fault protection is provided: Any short circuit or open circuit will disrupt service to the affected units.
3. The multiplexer can impose extensive space and power requirements.

Computer Interfaces

Various interface standards have been established in order to allow interoperability between the PC (personal computer) or workstation and its various connected elements. These standards usually relate to both mechanical and electrical interfaces, and include industry standard architecture (ISA), extended industry standard architecture (EISA), Personal Computer Memory Card Industry Association (PCMCIA), intelligent drive electronics (IDE), small computer system interface (SCSI), and others. Each added hardware unit usually utilizes a specific software driver for interoperability with the specific platform. These protocols are applicable to small distances only, and allow units to be housed within or nearby the PC or workstation enclosures. For example, equipping a PC for video capture could involve a plug-in ISA card housed within the PC on the motherboard, a video camera connected to the card, and a software driver. This configuration does not allow remote video monitoring.

Relevant Prior Art

The use of the same wire pair or pairs for both power and data communication is well known, and is widely used in telecommunications, from "Plain Old Telephone Service" ("POTS") to Integrated Services Digital Network (ISDN) and broadband services in the local-loop including other Digital Subscriber Line (xDSL)

technologies. Such a concept is described, for example, in US Patent 4,825,349 to Marcel, describing using two pairs for such a scheme. A DC-to-DC converter for such DC feeding is described, for example, in US patent 4,507,721 to Yamano et al.

The concept of power line communication (PLC) is also widknown. However, in most cases the connection is similar to a LAN environment, in which a single transmitter occupies the entire medium. Examples of such techniques include X-10 and the consumer electronics bus (CEBus, described in the EIA-600 standard). Much of this technology uses complex spread-spectrum techniques in order to accommodate problematic media (characterized by high amounts of noise and interference). Even with such improved technologies, however, the data rate obtained is relatively low.

Prior art in this field includes US Patent 5,684,826 to Ratner, US Patent 5,491,463 to Sargeant et. al, US Patent 5,504,454 to Daggett et al., US Patent 5,351,272 to Abraham, US Patent 5,404,127 to Lee et al., US Patent 5,065,133 to Howard, US Patent 5,581,801 to Spriester et al., US Patent 4,772,870 to Reyes, and US Patent 4,782,322 to Lechner et al. Other patents can be found in US Class 340/310 (sub-classes A/R and others) and International Class H04M 11/04.

The concept of using existing telephone wiring also for data communication is first disclosed in US Patent 5,010,399 to Goodman et al., where video signals superimposed over the telephone signals are used. However, the scheme used is of the bus type and has the drawbacks of that topology. Similarly, the idea of data transmission over a public switched telephone network (PSTN) using the higher frequency band is widely used in the xDSL systems, as is disclosed in US patent 5,247,347 to Litteral et al. The patent discloses an asymmetric digital subscriber line (ADSL) system. However, only a single point-to-point transmission is described over the local-loop, and existing in-house wiring is not discussed, and thus this prior art does not disclose how to configure a full multipoint network. Multiplexing xDSL data and the POTS/ISDN data uses FDM principles, based on the fact that the POTS/ISDN services occupy the lower portion of the spectrum, allowing for the xDSL system to use the higher bandwidth.

A home bus network using dedicated wiring is disclosed in US Patent 4,896,349 to Kubo et al., and a home automation network based on a power line controller (PLC) is disclosed in US Patent 5,579,221 to Mun. US Patent 4,714,912 to

Roberts et al. is the first to suggest communicating data over power lines not in bus topology but as 'break-and-insert'. However, only single conductor is used, and the receivers are all connected again using a bus topology.

In addition, U.S. Patent Application No. 08/734,921, Israel Patent Application No. 119454, and PCT Patent Application No. PCT/IL97/00195 of the present inventor disclose a distributed serial control system of line-powered modules in a network topology for sensing and control. These documents, however, do not disclose a local area network for data communications.

The prior art documents mentioned above are representative examples in the field. Certain applications are covered by more than one issued patent.

There is thus a widely recognized need for, and it would be highly advantageous to have, a means of implementing a local area network for data communications which does not suffer from the limitations inherent in the current methods. This goal is met by the present invention.

SUMMARY OF THE INVENTION

The present invention is of a local area network for data communication, sensing, and control based on serially connected modules referred to as "serial intelligent cells" (SIC's). An example of a local area network of such devices according to the present invention is illustrated in Figure 7, to which reference is now briefly made. In this example, SIC's **700**, **702**, **704**, **706**, and **708** are connected by one or more conducting wire pairs (such as a twisted pair **710**). This allows chaining, such as SIC **700** to SIC **702** to SIC **704**. However, SIC **700**, SIC **706**, and SIC **708**, located at the ends are equipped with single connection. SIC **704** is equipped with three connections, and even more connections are possible. A SIC may be interfaced to one or more DTE's, as illustrated by a DTE **714** interfaced to SIC **700** and by DTE's **716** and **718** interfaced to SIC **704**. SIC's need not have an interface, however, as is illustrated by SIC **706** and SIC **702**. SIC **702**, though, serves as a repeater, connecting SIC **700** and SIC **704**. It is to be noted that the networks according to the present invention utilize electrically-conducting media to interconnect the SIC's. Each electrically-conducting medium connects exactly two SIC's into a communicating pair of SIC's which communicate bidirectionally and independently of other

communicating pairs in the local area network. Electrically-conducting media are media which transmit signals by conducting electrical current or by propagating electrical potential from one point to another. Electrically-conducting media include, but are not limited to wires, twisted pair, and coaxial cable. But electrically-conducting media do not include media such as fiber optic lines, waveguides, microwave, radio, and infrared communication media.

As noted above, SIC's in a communicating pair communicate bidirectionally. For example, SIC **704** can initiate communication (as a sender) to SIC **702** (as a receiver), but SIC **704** can just as well initiate simultaneous communication (as a sender) to SIC **700** (as a receiver). Bidirectional communication can take place simultaneously, and herein is taken to be equivalent to "full duplex" communication. In addition, as noted above, the communication between the SIC's of a communicating pair is independent of the communication between the SIC's of any other communicating pair, in that these communications neither preclude nor affect one another in any way. Furthermore, every communication between SIC's is a "point-to-point communication", which term herein dena communication that takes place between exactly one sender and exactly one receiver. This is in contrast to a bus-based communication, in which there are many (potential) receivers and many (potential) senders. Consequently, in the topology according to the present invention, there is automatically a termination in the physical layer at each end of a connection (a SIC), both simplifying the installation and insuring more reliable communication.

The topology according to the present invention is superior to the prior art bus topology in the following ways:

1. There is no physical limit to the number of SIC's which may be installed in the network, and hence no physical limit to the number of DTE's in the network.
2. Point-to-point communication allows higher data rates over greater distances.
3. Point-to-point communication requires less complex circuitry than bus circuitry.

4. Several SIC's can transmit and receive simultaneously. For example, SIC **700** can communicate with SIC **702** while SIC **704** communicates simultaneously with SIC **706**.
5. There is no need for arbitration, allowing more efficient utilization of the network. Furthermore, priorities can be assigned to each SIC or, alternatively, to each specific message to allow the data routing to take care of priorities.
6. Addresses may be assigned by the network.
7. In the case of failure of any conductor or SIC, the network can sense the fault immediately, and the specific location of the fault (up to the specific SIC pair) is easily obtained.

Therefore, according to the present invention there is provided a local area network for data communication, sensing, and control including a plurality of serial intelligent cells interconnected exclusively by electrically-conducting media into at least one communicating pair, wherein: (a) each of the electrically-conducting media interconnects no more than two of the serial intelligent cells; (b) each of the communicating pair includes one of the electrically-conducting media and exactly two of the serial intelligent cells; (c) each of the communicating pair engages in a communication exclusively over the electrically-conducting media; and (d) each of the communicating pair engages in the communication bidirectionally and independently of the communication of any other of the communicating pair.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

Figure 1 shows a common prior art LAN bus topology.

Figure 2 shows a typical prior art multiplexer.

Figure 3 shows a prior art voice multiplexer (star topology).

Figure 4 shows a prior art voice exchange configuration (star topology).

Figure 5 is a block diagram of a SIC for data communications according to the present invention.

Figure 6 is a block diagram of a SIC for control applications according to the present invention.

Figure 7 shows a LAN topology utilizing the devices of the present invention.

Figure 8 shows an alternative LAN topology utilizing the devices of the present invention.

Figure 9 shows a SIC-based multiplexer - PABX/PBX according to the present invention.

Figure 10 shows a local area network according to the present invention used as a computer bus extender.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The principles and operation of a local area network according to the present invention may be better understood with reference to the drawings and the accompanying description.

Figure 5 is a block diagram of a representative SIC **500** for use in control applications. A first line interface **502** is a first port for connecting to the previous SIC to receive incoming electrical power and local area network data over electrically-conducting medium **503**, which may optionally be connected to an electrical power main **501**, so that SIC **500** may be powered from electrical power main **501**. Line interface **502** may include the connector, fuse, lightning arrester and other protection such as noise filters, etc. The incoming power/data signal is fed to a first power/data splitter/combiner **504**, which de-couples the (high frequency alternating current) data signal from the power. Such a power/data splitter/combiner **504** (denoted for brevity in Figure 5 as "P/D s/c") can be implemented by methods well-known in the art, such as using a center-tap transformer, or alternatively with active components. The data signal is fed to a first modem **506** allowing bidirectional communication, while the power is fed to a power supply **520**. The above scheme assumes that both power and data are carried by the same network wires (line-powering). Figure 5 illustrates the case where the SIC is line-powered by alternating current (for example, by the electrical power main), in which case power/data splitter/combiner **504** is an AC power/data splitter/combiner, which separates a low-frequency alternating current power from the higher-frequency data signal. Otherwise, in the case where the SIC is

line-powered by direct current, power/data splitter/combiner **504** is a DC power/data splitter/combiner, which separates direct current power from the data signal. In some cases the line-powering method is not used. For example, power can be carried by dedicated lines routed in conjunction with the data wiring. Alternatively, the SIC can be locally powered by a local power-supply. In both cases, the power/data splitter/combiner is not required, and the power lines are directly connected to the SIC power-supply, while the data connects directly to the modems. Parts of the SIC are shown optionally housed within an electrical outlet **524**, such that connections to the local area network as well as to the electrical power mains may be made from electrical outlet **524**. Electrical power from electrical outlet **524** can be fed to an optional electrical appliance **525**. In addition, SIC **500** contains an optional electrical power main feed **505** which can also power electrical appliances or other devices.

Power-supply **520** provides the required voltages for the SIC and payload operation, and also outputs the power to a second Power/data splitter/combiner **510**, for coupling to the next SIC. Communication with the next (fed) SIC is performed via a second modem **512** connected to a second line interface **514** via power/data splitter/combiner **510**, similar to power/data splitter/combiner **504** as previously described. Line interface **514** feeds to electrically-conducting medium **515**, which connects to the next SIC. Modems **506** and **512** can be standard RS-485, RS-232, or any simple similar data interface transceiver. Alternatively, a complex transceiver can be used for achieving long ranges or high-speed operation. CPU and firmware contained in a control block **522** control and monitor the unit operation and communication, as well as control the payload through a payload interface **508** interfacing with a payload illustrated by a sensor/actuator **509**. For example, interface **508** can implement a 4-20ma standard interface. In a similar way, SIC **500** can be used for communication over the power line. To do this, payload interface **508** is replaced by a communication port and sensor/actuator **509** will be replaced by a DTE.

A SIC for use in data communications as shown in Figure 5 is substantially similar to that used in control applications as shown in Figure 6, but has some specific differences as noted. Also illustrated in Figure 6 is the case where the local area network data is carried over electrically-conducting media which are part of the telephone wiring of a building. A SIC **600** has a first line interface **602** as a first port

for connecting to the previous SIC to receive incoming power, local area network data, and telephony data via an electrically-conducting medium **603**. Line interface **602** may include the connector, fuse, lightning arrester and other protection such as noise filters, etc. The incoming power/telephony/data signal is fed to a first telephony/data splitter/combiner **604** (denoted for brevity in Figure 6 as "T/D s/c"), which de-couples the local area network data from the power and telephony data. Such a telephony/data splitter/combiner **604** can be implemented by methods well-known in the art, such as using a high-pass/low pass filter, or alternatively with active components. The local area network data signal is fed to a first modem **606** allowing bidirectional communication, while the power (DC) is fed to a power supply **620**, and the telephony data is fed to power/telephone interface **624**.

Power-supply **620** provides the required voltages for the SIC and payload operation, and also outputs the power to a second telephony/data splitter/combiner **610**, for coupling to the next SIC. Communication with the next (fed) SIC is performed via a second modem **612** connected to a second line interface **614** via telephony/data splitter/combiner **610**, similar to telephony/data splitter/combiner **604** as previously described. Line interface **614** connects to an electrically-conducting medium **615**, which connects to the next SIC. Modems **606** and **612** can be standard RS-485, RS-232 or any simple similar data interface transceiver. Alternatively, a complex transceiver can be used for achieving long ranges or high-speed operation. CPU and firmware contained in a control block **622** control and monitor the unit operation and communication, as well as control the payload through a payload interface **608** interfacing with a payload **609**, which may include sensors and actuators. For example, interface **608** can implement a 4-20ma standard interface. SIC **600** also includes an optional power / telephone interface **624**, contained for example in a telephone outlet **625**, as well as one or more communications interfaces, such as a communication interface **626** connected to a DTE **628**.

In the case of DC line feeding, the power supply may be equipped with a line reversal function (for example, a diode-based bridge) in order to accommodate a possible wire reversal.

Note that a SIC can be implemented as single device with all component parts contained within one enclosure, but does not necessarily have to be so implemented.

In the case of a SIC used for data communications or control applications, the hardware may be optionally divided between the SIC module and the DTE/Payload units. In the case of a SIC used for telephone applications, the hardware may optionally be divided between the SIC, the DTE payload unit, and the telephone outlet, such as telephone outlet **625**, which allows connections to both telephone services (such as through a telephone **623**) and the local area network (such through DTE **628**). Telephone outlet **625** may be a wall outlet or jack. All or part of the SIC may be housed within a telephone outlet such as telephone outlet **625**, if desired. Furthermore, for SIC's used only as repeaters, a payload interface is not necessary.

Power/data splitter/combiner **510** (Figure 5) can use various techniques known in the art. Coupling can be implemented, for example, as disclosed in U.S. Patent 4,745,391 to Gajjar. Power-supply **520** (Figure 5) can be connected to the network using dedicated adapter or via specific SIC. The payload can also be connected using standard Ethernet or other LAN interface, hence emulating the network using the SIC's. This configuration makes use of standard interfaces, but operates at higher throughput and data-rates than a conventional LAN.

SIC Addressing

A SIC can include an address. Addresses of SIC's on the network can be assigned via automatic assignment by the local area network itself by algorithms known in the art, for example as disclosed in U.S. Patent 5,535,336 to Smith et al. Addresses can also be assigned via manual assignment, such as by the setting of mechanical switches on the SIC unit. Addresses can also be determined by the DTE connected to the SIC, either by means of higher layers as done in most LAN systems, or physically be means of the connection to the SIC (such as by address lines).

SIC Powering

A SIC can receive electrical power locally, via a power source located near the SIC. However, one power source may be used to power some or all the SIC's in the local area network using dedicated power lines. These lines can be routed with the data communication wires. Alternatively, the same electrically-conducting media (the data communication wires) can be used to carry both electrical power and local area network data to the SIC's, by means of techniques well-known in the art, for example,

as in telephone systems. In such a case, a unit is required for coupling the power supply to the local area network. This can make use of a SIC (such as SIC 706 in Figure 7) or in a specific dedicated module. Since electrical power is typically distributed at low frequencies (e.g., 60 Hertz), whereas local area network data is typically at a much higher frequency, electrical power can be combined with local area network data using frequency-domain multiplexing. A SIC can therefore be powered from the electrical power mains, and can also deliver electrical power, as illustrated in Figure 5 and detailed herein electrical power main 501, so that SIC 500 may be powered from electrical power main 501.

The DTE's, sensors, and actuators connected to the SIC's can also be locally powered from the SIC's, or can use the same power resources via the same channels as the SIC's. Part or all of a SIC can be housed within an electrical outlet so that the electrical outlet allows connection to the local area network as well as to electrical power.

Control

Although mainly intended to be used as communication network, the system according to the present invention can also be used as a platform to implement a sensing, control, and automation system. This is achieved by adding to one or more of the SIC's interfaces to sensors or actuators. The signals received by the sensors are transmitted over the network via logic contained in the SIC's or in the DTE's, which thereupon operate the relevant actuators. This automation function can be monitored by one or more of the DTE's.

The operation of the control may be associated with data communicated over the network (for example, sensing the availability of power to a DTE) or may be independent of it, to allow control decisions to be made locally.

DTE Interface

The DTE interface can be a proprietary interface or any standard serial or parallel interface, such as ITU-T V.35, ITU-T V.24, etc. In addition, a telephone interface (POTS) or ISDN may be used. This can suit intercom or PBX applications.

Fault Protection

The SIC topology described above can be modified to allow for single failure correction. In such a case, the SIC's are connected in a network with redundant paths, such as a circular topology as shown in Figure 8. In this example, a SIC **800** is connected to a SIC **802**, which is in turn connected to a SIC **804**, which is in turn connected to a SIC **806**, which is in turn connected to SIC **800**. When connected in such configuration, any single failure in any conductor, such as in conductor pair **810**, will not effect the system operation, as data routing from any SIC to any other SIC can be achieved via an alternate path. The term "circular topology" herein denotes the topology of any local area network of SIC's according to the present invention which contains at least two communication paths between two different SIC's. For example, in Figure 8, there are two communication paths from SIC **800** to SIC **804**: one communication path is from SIC **800** to SIC **802** to SIC **804**, and the other path is from SIC **800** to SIC **806** to SIC **804**. Circular topology provides redundant communication paths that increase the immunity of the local area network to communication faults. It should be noted that the circular topology according to the present invention, as shown in Figure 8, differs significantly from the well-known "Token Ring topology" of the prior art, as discussed following.

Although circular topology as defined herein can be superficially similar to the Token Ring topology, there are major differences between them. One difference is in the data framing. The Token Ring uses the same frame structure throughout all communication links in the network, and this requires that the same framing must be recognized by all the cells in the network. In the SIC network according to the present invention, however, each communication link (between any two connected SIC's) is totally independent from all other network communication. Hence, a first SIC can communicate with a second SIC using one type of frame structure and protocol, while the same first SIC can communicate with a third SIC using a different type of frame structure and protocol.

In addition, in a Token Ring network, there is single direction of data flow at any given time from a single transmitter to one or more receivers, and usually, the direction of data flow is constant. The SIC network according to the present invention, however, does not impose any limitation on the data flow in any of the

communication links. Full duplex, half duplex or unidirectional communication is possible, and can even vary from link to link throughout the network. This allows the SIC network to support two independent communication routes simultaneously, provided different segments are used. In Figure 8, for example, SIC **800** can communicate with SIC **802** while SIC **804** simultaneously communicates different data with SIC **806**. This capability is not supported by any of the other network configurations.

The above differences affects, for example, the vulnerability of the respective networks to faults. In case of single break or short-circuit anywhere in the medium, the Token Ring network will collapse, disabling any further communication in the system. As another example, in the network disclosed in U.S. Patent No. 4,918,690 to Markkula et al. (hereinafter referred to as "Markkula"), this fault affects the physical layer by disabling the media's signal-carrying capability. The Token Ring network will not function at all since the data layer functionality based on unidirectional transmission will not be supported. In contrast, however, a SIC network according to the present invention, will continue to function fully, except for the specific faulty link itself. All other links continue to function normally. Furthermore, the ability to localize the fault is not easily performed either in a Token Ring network or in the Markkula network. In the SIC network according to the present invention, however, it is simple and straightforward to trace the fault to the affected link.

Data Distribution over Electrical power Lines

An important configuration for a network according to the present invention uses the electrical power wiring of a building as a communication media. This can be used, for example, to implement an inexpensive 'home LAN'. Typical house mains have a connection to single feeder with numerous distribution points and outlets. The principles according to the present invention specify a SIC to be located within each outlet and at each distribution point. This will allow SIC-based communications network, where communication takes place between each pair of SIC's connected via the wiring. In such a case it is also expected that the mains will also be used to power the SIC's. Aside from using the same wiring media, the electrical distribution and the communication system sharing the same mains can be totally decoupled.

Another configuration involves adding the SIC to the Mains wiring at points distinguished from the mains outlets. The preferred embodiment, however, consists of using the outlets points for both the electrical supply and the DTE connection points. This involves replacing all electrical outlets and distribution points with 'smart' outlets, having both electrical connections and a communications jack. In addition, such unit may include visual indicators (e.g. LED's) to show the communication status, and may also include switches or other means to determine the outlet address. Such a communication system could be used for applications associated with power distribution, as for example to control the load connected to a specific outlet, for remote on/off operation of appliances, timing of operations, delayed start, disconnection after pre-set time period, and so forth. Such a communication system could also be used to monitor the power consumed by specific outlets, such as for Demand Side Management (DSM) or Automatic Meter Reading (AMR), allowing remote meter reading.

The above described topology may also apply to existing wiring. One common example may be power wiring to consumers located in different locations. Such wiring typically relies on bus topology with taps. In order to use SIC technology, the wiring must be broken, and a SIC installed between both ends.

In a similar manner, a communication network employing the electrical power wiring of vehicles and vessel can be implemented, such as for aircraft, ships, trains, buses, automobiles, and so forth.

Implementing a Local Communication / Telephone System using SIC's

In this application, existing telephone wiring (either POTS or ISDN) is used as the electrically-conducting media for the local area network, and is used for both local area network data communication and for telephony. The term "telephony" herein denotes any telephone or telephonic communication, including both including voice (POTS) and data (ISDN). Telephone outlets are usually connected in point-to-point topology without a distribution point. To set up a network, each outlet is replaced with SIC-based outlet. If there are distribution points, these distribution points must also be SIC equipped. This configuration results in a high-performance LAN between the telephone outlets. Aside from sharing the same media, the local area network can be decoupled from the telephone system. Alternatively, the local area network and the

telephone system can be combined, such that telephony is digitally integrated into the local area network data.

The outside telephone service can be treated according to one of the following alternatives:

1. No telephone support. In this configuration, the connection to the network (usually to the public network) is cut, and the network is fully internal, with no external telephone service.

2. Telephone as Payload. In this configuration, the telephone capability is retained, and telephony data may be integrated into the data communication of the local area network. One of the SIC's (usually the one closest to a public telephone network interface) or other dedicated module interconnects (via the communication interface, for example) to the network interface (NI). This unit emulates a telephone interface to the NI, so that public network operation is transparent and continues to perform as normal. However, the signals associated with the telephone interface, either the voice itself and the control / signaling (on hook / off hook, ringing, etc.) are digitized and transmitted in the network as data stream, as part of the communication taking place in the network. In the SIC's interfaced to telephones, these signals are converted back to analog (or in any original form) and thus can be used with standard telephones. In this case, telephone functionality is fully retained. However, failure in the communication network may result in loss of the telephone service. This can be improved by means of a system which disconnects the SIC's circuitry and restores the original wiring routing (this can be easily implemented by relays, which bypass the SIC's upon failure detection, manual intervention, or other relevant occasion).

3. Communication over POTS or ISDN. In this method, the electrically-conducting media interconnecting SIC's is the telephone wiring of a building. This method involves the known mechanism 'POTS Splitting', currently used in conjunction with xDSL technologies. This requires a filter which separates the low-frequency

portion of the spectrum (usually carrying the POTS associated signals and power) from the high-frequency portion of the spectrum (used for communication). In such an application, the AC/DC units in the SIC are replaced with such POTS splitter modules. The low-frequency band (POTS related) is passed transparently (similar to the power pass), and branched to the telephone jack. The high-frequency band is used for the communication between the SIC's. This combining of high-frequency local area network communication on the same electrically-conducting media with low-frequency telephony data is a form of frequency-domain multiplexing.

In the latter two alternatives, each in-wall telephone outlet is replaced with a SIC based outlet having both a telephone jack and one (or more) communication jacks.

Computer Bus Extender

The SIC network can be used as a computer bus extender, such as an 'ISA bus extender', as illustrated in Figure 10. In this configuration, a SIC **1006** is equipped with a computer bus connector **1004** which is connected, for example, to one of the ISA bus slots in a computer **1002**, to transport data between the local area network and computer **1002**. Another SIC **1010**, remotely located, also has a computer bus connector **1012**, such as an ISA bus extender. This allows for a transparent ISA bus capability, where the ISA bus data will be transported in both directions over electrically-conducting medium **1008**. The ellipses (...) indicate that additional SIC's and electrically-conducting media may be present in the local area network between SIC **1006** and SIC **1010**. Shown as an example, a video frame grabber card **1014** is plugged into computer bus connector **1012**, and a video camera **1016** is connected to video frame grabber card **1014**. Normally, video frame grabber card **1014** is plugged directly into an ISA bus slot, such as in computer **1002**. Here, however, the local area network acts as a bus extender so that video frame grabber **1014** and video camera **1016** can be located remotely from computer **1002**. The normal software driver for the ISA bus slot in computer **1002** can used, since computer **1002** is unaware of the fact that only ISA emulation is taking place. This way, the capability of having general remote PC components and peripherals can be easily achieved. This configuration

features the above-described advantages, and this method can be used to attain various goals, such as fault protection. Similarly, this method can be used to connect several units remotely to a computer, using different ports in the computer.

Implementing Multiplexers and PABX/PBX Functionality

A network of SIC's may be used to implement a multiplexer or a PABX/PBX functionality, as illustrated in Figure 9. In this example, a SIC **900** is connected to a high data rate connection, such as PCM bus **916**, while SIC **902** and SIC **906** are connected to telephones **908**, **910**, and **912**. SIC **904** functions as a repeater in this example.

In this example, the local area network functions as a multiplexer, wherein the bandwidth of the high data rate connection (PCM bus **916**) is multiplexed through SIC **900** to SIC **902** and SIC **906**, each of which may use a different portion of the bandwidth of the high data rate connection (PCM bus **916**). Moreover, by the addition of telephones **908**, **910**, and **912**, the local area network of Figure 9 functions as a voice multiplexer.

Other Applications of the Invention

A number of applications of the present invention have been discussed above. Additional applications include, but are not limited to: intercom, PABX/PBX, security systems, video surveillance, entertainment broadcasting services, time (clock) distribution, and audio/video signal distribution. The networks implemented by the present invention can extend locally within a single building or over a neighborhood.

While the invention has been described with respect to a limited number of embodiments and applications, it will be appreciated that many variations, modifications and other applications of the invention may be made.

WHAT IS CLAIMED IS:

1. A local area network for data communication, sensing, and control comprising a plurality of serial intelligent cells interconnected exclusively by electrically-conducting media into at least one communicating pair, wherein:

(i) each of said electrically-conducting media interconnects no more than two of said serial intelligent cells;

(ii) each of said at least one communicating pair includes one of said electrically-conducting media and exactly two of said serial intelligent cells;

(iii) each of said at least one communicating pair engages in a communication exclusively over said electrically-conducting media; and

(iv) each of said at least one communicating pair engages in said communication bidirectionally and independently of the communication of any other of said at least one communicating pair.

2. The local area network as in claim 1, wherein said communication is exclusively point-to-point communication.

3. The local area network as in claim 1, wherein the topology is a circular topology.

4. The local area network as in claim 1, wherein at least one of said electrically-conducting media includes electrical power wiring of a building.

5. The local area network as in claim 1, wherein at least one of said electrically-conducting media includes telephone wiring of a building.

6. The local area network as in claim 1, wherein at least one of said electrically-conducting media is used for both local area network data and for telephony.

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7. The local area network as in claim 6, wherein the local area network data and telephony are combined by frequency-domain multiplexing.

8. The local area network as in claim 1, wherein at least one of said plurality of serial intelligent cells is powered from an electrical power main.

9. The local area network as in claim 1, wherein at least one of said plurality of serial intelligent cells can deliver electrical power.

10. The local area network as in claim 1, wherein at least one of said electrically-conducting media is used to carry both local area network data and electrical power.

11. The local area network as in claim 10, wherein the local area network data and electrical power are combined using frequency-domain multiplexing.

12. The local area network as in claim 1, wherein at least part of at least one of said plurality of serial intelligent cells is housed within a telephone outlet.

13. The local area network as in claim 12, wherein the telephone outlet allows connections to telephone services and to the local area network.

14. The local area network as in claim 1, wherein at least part of at least one of said plurality of serial intelligent cells is housed within an electrical outlet.

15. The local area network as in claim 14, wherein the electrical outlet allows connections to electrical power and to the local area network

16. The local area network as in claim 1, wherein telephony is digitally integrated into the local area network data.

17. The local area network as in claim 1, wheat least one of said plurality of serial intelligent cells includes an address.

18. The local area network as in claim 17, wherein said address is assigned via a method selected from the group consisting of manual assignment and automatic assignment by the local area network.

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19. The local area network as in claim 1, wherein at least one of said plurality of serial intelligent cells receives electrical power locally.

20. The local area network as in claim 1, wherein at least one of said plurality of serial intelligent cells receives electrical power via a dedicated power line.

21. The local area network as in claim 1, wherein at least one of said plurality of serial intelligent cells comprises:

(i) a linc interface;

(ii) a modem;

(iii) a control block; and

(iv) a power supply.

22. The local area network as in claim 1, wherein at least one of said plurality of serial intelligent cells receives electrical power via said electrically-conducting media.

23. The local area network as in claim 22, wherein at least one of said plurality of serial intelligent cells comprises a telephony/data splitter/combiner.

24. The local area network as in claim 22, wherein at least one of said plurality of serial intelligent cells comprises a power/data splitter/combiner.

25. The local area network as in claim 24, wherein said power/data splitter/combiner comprises an AC power/data splitter/combiner.

26. The local area network as in claim 24, wherein said power/data splitter/combiner comprises a DC power/data splitter/combiner.

27. The local area network as in claim 21, wherein at least one of said plurality of serial intelligent cells further comprises:

(v) a payload interface; and

(vi) at least one device selected from the group consisting of a sensor and an actuator.

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28. The local area network as in claim 21, wherein at least one of said plurality of serial intelligent cells further comprises:

(v) a communications interface.

29. The local area network as in claim 21, wherein at least one of said plurality of serial intelligent cells further comprises:

(v) a computer bus connector.

30. The local area network as in claim 29, functioning as a computer bus extender.

31. The local area network as in claim 21, wherein at least one of said plurality of serial intelligent cells further comprises:

(v) a telephone interface.

32. The local area network as in claim 31, wherein one of said plurality of serial intelligent cells is interconnected to a public telephone network interface.

33. The local area network as in claim 1, functioning as a multiplexer, wherein at least one of said plurality of serial intelligent cells is connected to a high data rate connection whose bandwidth is multiplexed to at least one other of said plurality of serial intelligent cells.

34. The local area network as in claim 33, functioning as a voice multiplexer, wherein at least one of said plurality of serial intelligent cells is connected to a telephone.

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