TECHNOLOGY OVERVIEW SERIES

CIP on TDMA Technology

PUB00161R1 MARCH 2016

CompoNet™ – CIP on TDMA

CompoNet™ is a field network designed for applications dominated by distributed field devices, each with few I/O points. It features high-speed communication, provides flexible topology, reduces wiring labor, and helps to cut down on troubleshooting and maintenance work. CompoNet is a member of a family of networks that implements the Common Industrial Protocol (CIP™) at its upper layers. CIP encompasses a comprehensive suite of messages and services for a variety of manufacturing automation applications, including control, safety, synchronization, motion, configuration, diagnostics and information. As a truly media-independent protocol that is supported by hundreds of vendors around the world, CIP provides users with unified communication architecture throughout the manufacturing enterprises.

With media independence comes the ability to choose a CIP Network best suited for each application. One of these possible choices is CompoNet, which adapts CIP to TDMA (Time Domain Multiple Access) on a simple 2-wire physical layer. TDMA assures each device a fixed time slot in the communication cycle, resulting in low overhead and strict cycle times. This efficiency allows large numbers of nodes to share small amounts of data, without requiring extremely high baud rates. As a consequence, CompoNet can reliably run on inexpensive unshielded 2-wire cable.

CompoNet offers several unique advantages for automation applications:

- Fast cyclic exchange of bit- and word-sized data, making it a high performance network for sensors and actuators.
- Cyclic I/O data which can be distributed over up to 384 nodes.
- CIP messaging, allowing intelligent field devices to be configured and maintained remotely.
- A wide range of data rates (93.75kbps to 4Mbps), allowing a flexible trade-off between speed and distance.
- 4-wire flat cables allowing easy installation, or cost-efficient unshielded 2-wire cable.
- Up to 64 repeaters, enabling a large number of nodes and coverage of wide areas with complex topologies.

Typical applications of CompoNet are:

- Wire-saving in modular machines. With submillisecond cycle times at the higher baud rates, a single flat cable can link machine modules without loss of performance.
- Conveyor and warehouse applications. With I/O points few and far apart, the free network topology at the low baud rate will cut down wiring cost. Repeaters can extend the covered area.
- Data collection applications where ease of communications via EtherNet/IP™ to plant host computers is a must.

Here's a more in-depth look at the technology behind every CompoNet-compliant product.

What is CompoNet?

CompoNet, like other CIP Networks, follows the Open Systems Interconnection (OSI) model, which defines a framework for implementing network protocols in seven layers: physical, data link, network, transport, session, presentation and application. Networks that follow this model define a complete suite of network functionality from the physical implementation through the application or user interface layer. As with all CIP Networks, CompoNet implements CIP at the Session layer and above while adopting CompoNet specific definitions at the Transport layer and below. This network architecture is shown in Figure 1.

By employing a subset of all available CIP functions, and some simplifications in the Transport Layer, CompoNet implementation is significantly 'lighter' than other networks. Yet, while still being a lower layer of the CIP Network family, CompoNet is still able to provide all basic functions of CIP. Implementation of the Session layer and above is fundamentally the same as other CIP Networks with only minimal adaptations.

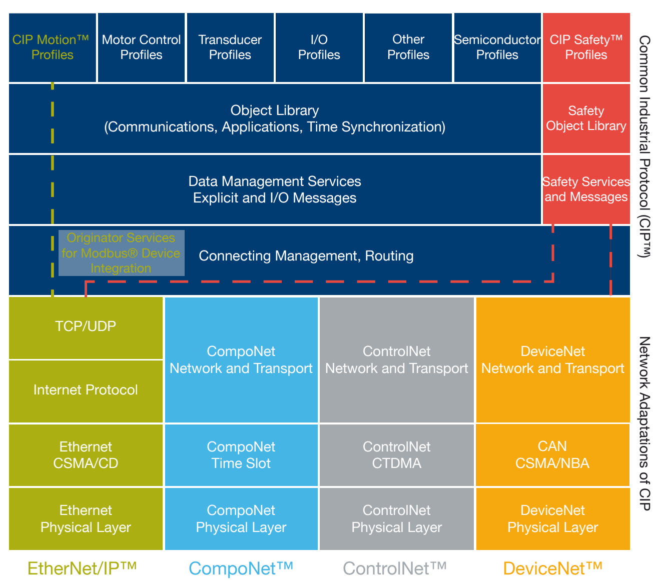

Figure 1: CompoNet as Part of the CIP OSI Model

The Physical Layer

CompoNet's physical layer was derived from RS485 specifications. The use of Manchester signal coding technology along with a pulse transformer in the physical layer improves the reliability of the communication. These additions make it possible to use cheap unshielded cables. The pulse transformer isolates each device from the communication line and reduces signal disturbance. The pulse transformer is connected in a fashion that enables the doubling of transmit voltages, while requiring lower threshold voltages on the receive side. This technique increases the magnitude of the signal at the receiving end.

In addition, CompoNet implements a special "Receive mask." The mask is accomplished using advanced digital signal filtering. This allows the use of cables of different electrical characteristics, and realizes transmission in various data rates. Receive masks have following features.

- Reduced voltage and skewed signals can be more readily and reliably be received and decoded.
- Noise rejection of spike and reflected waveforms is greatly increased.

CompoNet network technologies allow the use of dedicated repeaters. Repeaters extend the maximum trunk line length and expand the installation area. Furthermore, they greatly increase the number of connectable nodes, and allow mixed use of different types of cables.

As shown in Figure 2, repeaters can extend the maximum trunk line length to three times the standard length. Use of maximum 64 repeaters can expand the installation area, and allow the connection of a large number of nodes. The repeaters divide the network into multiple layers, and allow the mixed use of flat and round cables. This enables various topologies such as cost-effective round cables for the trunk line and easy to install flat cables for sub-trunk lines.

In addition, TDMA minimizes the transmission delay due to repeaters, and decreases its influence on the communication cycle. Key to the use of repeaters is the ability of the remote slaves to "know" their location in the network, and transmit I/O data just before it is required on the backbone. There is, therefore, no delay in communication with the master due to delays in the response of the slaves.

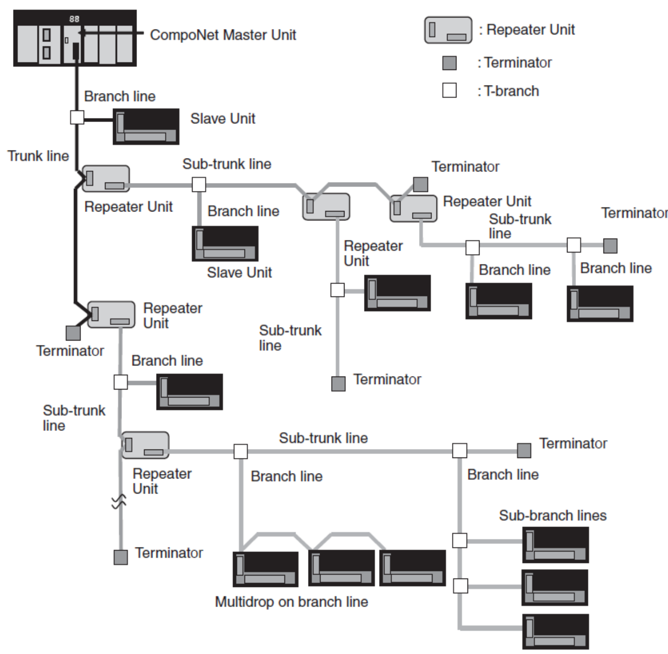

Figure 2: CompoNet topology example

The Data Link Layer

MAC (Media Access Control) generates and analyzes the CompoNet communication frames.The MAC layer has the following functions to satisfy CompoNet transmission quality and high-speed.

- Manchester coding
- CRC generation/check
- Adding a special preamble (a start code) to accomplish no gaps (zero inter-frame delay between frames). This means that there is none of the idle time on the wire that is typical of some other networks.

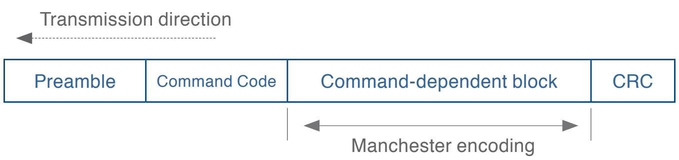

Figure 3: Frame block

TDMA (Time Domain Multiple Access) controls the CompoNet frame transmission and reception. In the CompoNet network, the master controls frames on the wire at optimal states in order to improve the network efficiency. There are 7 types of frames in CompoNet such as OUT, TRG, BEACON, CN, IN, A_EVENT and B_EVENT frames. The master directly controls OUT, TRG, BEACON, A_EVENT and B_EVENT frames. However, it does not control CN and IN frames that are sent by slaves. The master sets the appropriate, optimized timing for the slave to send those frames, at the time the slave participates in the network. The timing being described is the period of time after receiving an OUT or a TRG frame for a slave to transmit its data.

One of the main characteristics of TDMA is the minimization of transmission delay due to repeaters. With some other networks, a substantial transmission delay occurs at a repeater since it typically receives, reforms, and resends the signals, in order to properly capture and check the frames. Therefore, a repeater delay must be considered in the frame transmission timing. A gap must be provided between frames to avoid their collision. For example, if 2 repeaters are used in a network, the required gap will be four times of a repeater delay period.

CompoNet requires no gap between frames by having the CN and IN frames restrict the repeaters to transmit data only through a master port to a slave port (Repeat operation from the slave port is not allowed. It must go back through the master.) CN and IN frames are sent out to the wire earlier to offset delays caused by repeaters.

On a CompoNet network, IN and OUT frames can be used in variable sizes as to the number of I/O points. This is to accomplish network efficiency. Moreover, multiple MAC IDs are provided separately for bit node and word node. This improves usability and simplifies the implementation for vendors.

The CompoNet protocol provides several functions to improve maintainability, in addition to I/O and explicit messaging.

- Gathering slave information by CN frame. It notifies the master of an error state of slave through 4-bit flags embedded in the data frame.It can detect an error state without signaling from master.
- Getting slave information by STR (Status read by B_EVENT frame). STR indicates which nodes are connected to which repeaters. This information enables the tools to understand the network configuration and get a sense of its topology.
- STR also provides information that describes a slave. Such information includes vendor ID, device type and product code. By reading STR data stored in the master, the tools can speedily scan the network configuration and collect detailed information about all devices connected to it.
- Baud rate synchronization by BEACON frame. The master notifies a slave of its baud rate. This allows easy synchronization.

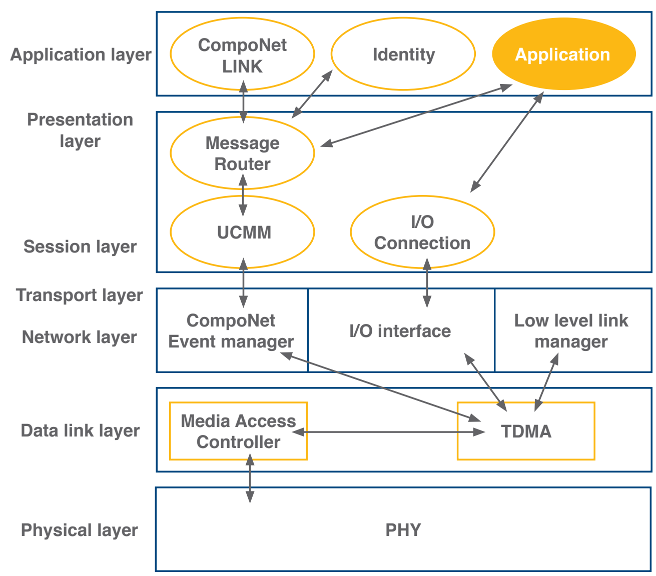

Figure 4: OSI Layer details

The Network and Transport Layer

Because CompoNet uses UCMM (Unconnected Message Manager) to send or receive the explicit message protocol, the master must be aware of the existence of the destination (slave) in advance of sending it messages. Furthermore, the master must establish the transmission timing of IN and CN frames to slaves prior to sending the frames. Therefore, CompoNet controls slave participation (as participated state or non-participated state) in the Transport layer.

The master detects the existence of slaves through CN frames. When master receives a CN frame from non-participated slave, it automatically processes the participation state of the slave. STR or STW (Status write by B_EVENT frame) is used for participation processing. Explicit messages (A_EVENT message) are sent to the slaves who are in the participated state. STW is to notify the slave of CnTimeDomain, InTimeDomain and OutBlockPointer, which are required for implementing TDMA. In accordance with the received TimeDomain notification, the slave responds with an IN frame and a CN frame, and then retrieves its OUT data from the OUT frame.

After the participation process, an explicit message then implements allocation of the Predefined connection set. When a slave in participated state does not respond to CN frames or IN frames for an extended period of time, then the master regards the slave to be in the network timeout state.

The I/O interface passes on IN or OUT data between TDMA and upper layers. The IN and OUT data are updated automatically by TDMA. The I/O interface gets IN data and transmits OUT data for TDMA. TDMA manages allocation of OUT data via the OUT frames. The I/O interface reallocates the OUT data which are transferred by the upper layer to the format managed by TDMA.

The CompoNet Event manager controls the explicit message fragmentation. It also monitors the responses and retries to send the explicit messages in its unique manner, since CompoNet uses UCMM to send and receive the explicit messages. The CompoNet Event manager buffers the explicit messages sent by the upper layers. It requests TDMA to send Events. Before sending a request to TDMA, it divides a long explicit message into smaller fragments.

TDMA notifies the CompoNet Event manager of the explicit message response. A long response is divided into smaller fragments when the CompoNet Event manager receives it. The CompoNet Event manager recomposes the fragments to an explicit message response, and sends the whole message to the upper layer. The CompoNet Event manager monitors the responses. When there is no response for an extended period of time, the CompoNet Event manager either retries the sending of the message or it processes a time-out.

The Upper Layers

CompoNet uses the Common Industrial Protocol (CIP), a strictly object-oriented protocol, at the upper layers. Each CIP object has attributes (data), services (commands) and behaviors (reactions to events).

CIP also defines “device types” which includes “device profiles.” The device profile specifies the set of CIP objects that must be implemented for a given device type, the configuration options and the I/O data formats. This consistency in object implementation per device type has several advantages. Users of CIP Networks can promote a common application interface for a given device type, and increase interoperability in networks comprised of devices from multiple vendors. The vendors can add specific objects to a CompoNet-compliant product, and support the functional requirements of particular applications.

Seamless bridging and routing is perhaps the most significant advantage for users of CIP Networks. It is this mechanism that most benefits the user’s investment for the future. The ability to originate a message on one CIP Network, such as EtherNet/IP, and then pass it to another CIP Network, such as CompoNet, with no presentation at the Application Layer, means that users can incorporate incremental application improvements to existing installations and/or integrate automation systems with diagnostic, prognostic and/or IT applications. Seamless bridging and routing between both homogeneous and heterogeneous CIP Networks is enabled by a set of objects that defines routing mechanisms for a device to use when forwarding the contents of a message produced on one network port to another. This mechanism does not alter the contents of a message during the routing process. When using this mechanism, the user’s only responsibility is to describe the path that a given message must follow. CIP ensures that the message is handled correctly, whichever the CIP network type is involved.

Management of the CompoNet Technology

CompoNet is managed by ODVA, an international association of the world's leading automation companies. ODVA's CompoNet management responsibilities include:

- Publishing The CompoNet Specification;
- Overseeing the process to incorporate new enhancements to The CompoNet Specification;
- Licensing the CompoNet Technology to companies desiring to make and/or sell CompoNet-compliant products;
- Promoting industry awareness of CompoNet and its benefits; and
- Helping to ensure compliance of CompoNet products with the specification through conformance testing and conformity reporting.

For more information about CompoNet, CIP or ODVA, visit ODVA at **www.odva.org**.

About ODVA

Founded in 1995, ODVA is a global association whose members comprise the world's leading automation companies. ODVA's mission is to advance open, interoperable information and communication technologies in industrial automation. ODVA recognizes its media independent network protocol, the Common Industrial Protocol or "CIP" – and the network adaptations of CIP – EtherNet/IP, DeviceNet, CompoNet and ControlNet – as its core technology and the primary common interest of its membership. ODVA's vision is to contribute to the sustainability and prosperity of the global community by transforming the model for information and communication technology in the industrial ecosystem. For future interoperability of production systems and the integration of the production systems with other systems, ODVA embraces the adoption of commercial-off-the-shelf (COTS) and standard, unmodified Internet and Ethernet technologies as a guiding principle wherever possible. This principle is exemplified by EtherNet/IP – the world's number one industrial Ethernet network. For more information about ODVA, visit odva.org.

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PUB00161R1