Echelon’s Control Ecosystem
The Pyxos & LONWORKS® Platforms

Legend:
- LONWORKS Control Network
- Pyxos Embedded Control Network

Network Operations Center

INTERNET

i.LON® 100

Pyxos Room
Pyxos Machine
LONWORKS Device

Legend
The Pyxos & LONWORKS Platforms

**Key Differentiators**

- **The LONWORKS Platform**
  - Ideal for control networks including building, home, transportation, and industrial systems
  - Scales to millions of devices
  - Integrates the Internet, existing buses, web services
  - Peer-to-peer architecture
  - Control backbone for wired or wireless sensor networks

- **The Pyxos Platform for Embedded Control Networks**
  - Ideal for extending LONWORKS networks to smallest sensor or device
  - Very high speed, deterministic performance
  - Master/slave architecture
  - Ideal sensor networking platform for up to 32 devices
  - Use LONWORKS control networks as communications backbone
  - Price/performance to embed networks inside machines
    - Replaces complex wiring harnesses & simple bus technologies
Contents

- Introduction to Pyxos FT Networking Technology
- Link Layer Protocol Overview
- Hardware Design Considerations
- System Design and Application Development
- Features Comparison with Other Technologies
All communication goes through the Pilot
**Bus Topology**
- 400 meters max
- 0.3 meter stubs
- Terminated at both ends
- Up to 32 Points

**Free Topology**
- Combination of star, loop, daisy chain or bus
- 100 meters max
- Single termination anywhere
- Up to 32 Points
Pyxos Point

Unhosted Point

- No µC needed
- 4 digital I/Os
- 1 digital Input
- Most cost-effective design for simple nodes

Hosted Point

- Use µC based on application requirement
- SPI connection to host µC
- Use I/O connections on host µC
- 10MHz clock available from Pyxos chip
Host µC is Required for Pilot Design
- Host processor is moderate to high end
- SPI interface between Pyxos Chip and Host µC
- 10 MHz clock available from Pyxos chip

Link Power Source Optional
- Either Pilot or any Point on the Pyxos network can be power source

Pilot Variations
- Stand Alone – Not connected to other networks
- Networked – Uses LONWORKS networks (or others) to connect to control applications or Internet
## Pyxos Networks – Key Features

<table>
<thead>
<tr>
<th>Features</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>Free Topology, Link Power, twisted-pair transceiver</td>
</tr>
<tr>
<td>Network Connections</td>
<td>Polarity-insensitive</td>
</tr>
<tr>
<td>Protocol</td>
<td>Deterministic Time Division Multiplexed (TDM) protocol with automatic retries</td>
</tr>
<tr>
<td>on any CRC error</td>
<td></td>
</tr>
<tr>
<td>MAC ID</td>
<td>Built-in</td>
</tr>
<tr>
<td>Installation</td>
<td>Self-organizing network with automatic, hardwired, and manual service-pin</td>
</tr>
<tr>
<td>methods</td>
<td></td>
</tr>
<tr>
<td>Maximum Pyxos points per Pyxos Pilot</td>
<td>32</td>
</tr>
<tr>
<td>Transmission Rate</td>
<td>312.5 kilobits per second, fixed polling cycle</td>
</tr>
<tr>
<td>Pyxos Network Variables (PNVs) per hosted</td>
<td>128 four-byte PNVs per Pyxos Point. Larger size PNVs can be defined within</td>
</tr>
<tr>
<td>Pyxos Point</td>
<td>total memory size available</td>
</tr>
<tr>
<td>Data Integrity</td>
<td>Forward Error Correction of up to 2 bit errors per packet; 18 bit packet CRC</td>
</tr>
<tr>
<td>LONWORKS Network Variables per Pyxos Pilot</td>
<td>62 when using ShortStack, 4096 when using MIP</td>
</tr>
<tr>
<td>Response Time</td>
<td>25ms scan time for 32 Pyxos Points. Scan time is dependent on the total number</td>
</tr>
<tr>
<td></td>
<td>of Pyxos Points, e.g., 1.8ms for 2 Pyxos Points.</td>
</tr>
<tr>
<td>Communication Distance</td>
<td>Single termination (free topology):</td>
</tr>
<tr>
<td></td>
<td>100m maximum total wire</td>
</tr>
<tr>
<td></td>
<td>Double termination: 400m maximum, 0.3m max stub length</td>
</tr>
<tr>
<td>Network Wiring</td>
<td>Unshielded CAT-5 24AWG (0.5mm) and Belden 8471 16AWG (1.3mm) twisted pair</td>
</tr>
<tr>
<td></td>
<td>wire</td>
</tr>
</tbody>
</table>
## Pyxos Networks – Key Features (contd.)

<table>
<thead>
<tr>
<th>Features</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Link Power</td>
<td>Supports 24VAC or 24VDC link power with optional external components; Reference designs provided for both switching and linear power supplies</td>
</tr>
<tr>
<td></td>
<td>Application Output Current: up to 100mA @ 3.3V DC</td>
</tr>
<tr>
<td>Coupling Options</td>
<td>Direct connect (for applications within a single enclosure)</td>
</tr>
<tr>
<td></td>
<td>Non-isolated/Grounded</td>
</tr>
<tr>
<td></td>
<td>Non-isolated/Floating</td>
</tr>
<tr>
<td></td>
<td>Transformer-isolated</td>
</tr>
<tr>
<td>ESD (IEC 61000-4-2)</td>
<td>Designed to comply with 61000-4-2 Level 4 (contact - 8kV; air - 15kV)</td>
</tr>
<tr>
<td>ESD (HBM) (for network pins)</td>
<td>8kV</td>
</tr>
<tr>
<td>Common Mode range (0 – 60Hz)</td>
<td>277Vrms with Transformer-isolated coupling</td>
</tr>
<tr>
<td></td>
<td>+/-40V with Non-isolated/Grounded coupling</td>
</tr>
<tr>
<td>Conducted RF immunity (IEC 61000-4-6)</td>
<td>Designed to comply with 61000-4-6 Level 3 (10Vrms)</td>
</tr>
<tr>
<td>I/O</td>
<td>4 digital I/Os and 1 digital input without a microcontroller (5V tolerant)</td>
</tr>
<tr>
<td>Pyxos Host Microcontroller Interface</td>
<td>SPI (Serial Peripheral Interface)</td>
</tr>
<tr>
<td>Pyxos Pilot Power Supply Output (VDD)</td>
<td>3.3V ±10%</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>-40C to +85C</td>
</tr>
<tr>
<td>Package</td>
<td>20 Pin QFN 5 x 5 mm package</td>
</tr>
</tbody>
</table>
A Pyxos chip can be configured as a Pilot or a Point

SPI port pins for a hosted Point and I/O pins for an unhosted Point are shared.
Pyxos Point Memory Map

1k x 8 bit

0x3FF
Point Control Registers

0x280
Reserved

0x1FF
Pyxos Chip Values

0x000
SPI address

256 x 32 bit

0xFF
Point Control Registers

0xA0
Reserved

0x7F
PCV (Pyxos Chip Values)

0x00
PCI (Pyxos Chip Index)

Resides in the Pyxos chip memory

HOT
Pyxos Chip Value

7...0
32 bit Register

PCI (Pyxos Chip Index)

Stays Local (except UID)

Sent to Pilot over network
Pyxos Pilot Memory Map

- SPI address: 0x000
- Read Timeslots: 0x140 - 0x3FF
- Write Timeslots: 0x000 - 0x13F
- Pilot Control Registers: 0x27F - 0x280

10 bytes

- HOT
- PCV

Sent on the network

32 bit

- Point Control Registers
- Reserved
- PCV (Pyxos Chip Values)

Resides in the Pilot Host µC memory
Pyxos Network Frames

- Frames are sent continuously in Pilot Auto mode
  - Frames can be sent manually to save power
- Each frame has both read and write slots
- Frame rate depends on the number of slots

<table>
<thead>
<tr>
<th>Description</th>
<th>time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start of Frame</td>
<td>278.4 us</td>
</tr>
<tr>
<td>Write timeslot</td>
<td>355.2 us</td>
</tr>
<tr>
<td>Read timeslot</td>
<td>416 us</td>
</tr>
<tr>
<td>Frame time (2 slots)</td>
<td>1.8 ms</td>
</tr>
<tr>
<td>Frame time (32 slots)</td>
<td>25 ms</td>
</tr>
</tbody>
</table>
Pyxos Network Frame Contents

- **SOF**
  - Synch
  - # slots
  - CRC18

- **Write Slots**
  - 2*[PCI,PCV]
  - TID flag
  - ACK flag
  - ACKd TID flag
  - CRC18

- **Read Slots**
  - Synch
  - 2*[PCI,PCV]
  - TID flag
  - ACK flag
  - ACKd TID flag
  - CRC18

Note: TID - Transaction IDentification
Pyxos FT
Hardware Design Considerations
Pyxos Chip Transceiver

- Differential transmit output impedance ~ 120 ohms
- Differential receive input impedance ~ 13k ohms
Pyxos Modulation Format

- **Manchester**
  - Biphasic PSK with $F_c = F_b$
  - Shaped to minimize reflections
  - Each bit is 1 cycle of 312.5 kHz
  - Preamble coding makes the channel polarity independent
Link Power Concept

Pyxos Link Power – Supports 24VAC or 24VDC for Link Power
### Link Power – Point Power Supply

**Diagram:**
- AC/DC Supply
- LP Filter
- C1
- L1
- L2
- NET1
- NET2
- VDD3

**Switching Power Supply OR Linear Power Supply**

**Table: Parameter Comparison**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Switching Power Supply</th>
<th>Linear Power Supply</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Voltage Range</td>
<td>8.5V – 40V</td>
<td>8.5V – 40V</td>
<td>V</td>
</tr>
<tr>
<td>Output Voltage</td>
<td>3.3V ±10%</td>
<td>3.3V ±10%</td>
<td>V</td>
</tr>
<tr>
<td>Approximate Cost</td>
<td>~1.75</td>
<td>~0.75</td>
<td>$@10k</td>
</tr>
<tr>
<td>Application Current</td>
<td>100</td>
<td>35</td>
<td>mA</td>
</tr>
<tr>
<td>Power Unit Loading</td>
<td>1</td>
<td>½</td>
<td>½</td>
</tr>
</tbody>
</table>

- A Pyxos link powered network can support up to 32 PULs
- Reference designs available for both switching and linear power supplies
Factors that affect power limited distance

- Wire size
- Bus or Free topology
- AC or DC power source
- Number of Power Unit Loads (PULs) on each segment from the power source
- Distribution of PUL’s on each segment

Initially assume all PULs at end of segment

Uniform PUL distribution doubles the distance

Think of the distance to the “center of gravity” of the PULs on a segment
## Link Power – Maximum Distance

- Length to “center of gravity” of each leg from power source

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>Belden 8471 Cable</th>
<th></th>
<th>Cat 5 Cable</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bus</td>
<td>Free</td>
<td>Bus</td>
<td>Free</td>
</tr>
<tr>
<td>PULs</td>
<td>AC</td>
<td>DC</td>
<td>AC</td>
<td>DC</td>
</tr>
<tr>
<td>4</td>
<td>400</td>
<td>400</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>8</td>
<td>330</td>
<td>400</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>12</td>
<td>208</td>
<td>263</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>16</td>
<td>145</td>
<td>195</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>20</td>
<td>108</td>
<td>155</td>
<td>86</td>
<td>100</td>
</tr>
<tr>
<td>24</td>
<td>84</td>
<td>126</td>
<td>71</td>
<td>100</td>
</tr>
<tr>
<td>28</td>
<td>67</td>
<td>108</td>
<td>61</td>
<td>100</td>
</tr>
<tr>
<td>32</td>
<td>52</td>
<td>92</td>
<td>52</td>
<td>92</td>
</tr>
</tbody>
</table>

- Assuming maximum average wire temperature of 55°C
- Above table assumes all PULs at same point; Link Power distance can be increased by distributing the loads
What is Common Mode Noise?

- “In practical systems, ground potentials vary widely from node to node, often exceeding the [RS485, +12 -7V] specified range” - Linear Tech Design Note 228
- “Many applications see common-mode voltages beyond this range, such as +/-24V” - National Semiconductor Application Note 979
Pyxos FT technology covers a wide range of common mode requirements with multiple coupling options.
Coupling Transformer Information

- Transformers available directly from Transtek Magnetics

1. DIMENSIONS (UNIT: mm)

   - **A** = 14.0 MAX
   - **B** = 11.0 MAX
   - **C** = 10.0 MAX
   - **D** = 2.50 ± 0.3

   ![Diagram of TM300 YYWW transformer](image)

   - **TOP VIEW**
   - **FRONT VIEW**
   - **BOTTOM VIEW**

MARKING: YY:YEAR WW:WEEK

2. PCB LAYOUT

   - **2.5**
   - **1.0**
   - **14.0**
   - **2.0**

   ![Diagram of PCB layout for TMS80040CS](image)

   - **SIDE VIEW**
   - **SIDE VIEW**
   - **SIDE VIEW**

   - **Coplanarity 0.1 MAX**

   TMS80040CS

David Benitez
Transtek Magnetics
1900 W. Grant Road
Tucson, AZ USA 85745
(800) 378-0015
avidb@transtekmagnetics.com
## Coupling Option Summary

<table>
<thead>
<tr>
<th>Coupling Type</th>
<th>Application</th>
<th>Node Power</th>
<th>Node Grounding</th>
<th>CMR DC-60Hz</th>
<th>CMR &gt;100kHz</th>
<th>~Coupling Cost $@10k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>Same Box</td>
<td>Common</td>
<td>Common</td>
<td>0-VCC3</td>
<td>0-VCC3</td>
<td>0.00</td>
</tr>
<tr>
<td>Non-Isolated</td>
<td>Network</td>
<td>Link or Local</td>
<td>Local</td>
<td>+/-40V</td>
<td>1VRMS</td>
<td>0.15</td>
</tr>
<tr>
<td>Floating</td>
<td>Network</td>
<td>Link or Local</td>
<td>Floating</td>
<td>Isolation Limit</td>
<td>10VRMS</td>
<td>0.15</td>
</tr>
<tr>
<td>Transformer Isolated</td>
<td>Network</td>
<td>Link or Local</td>
<td>Local</td>
<td>277VAC</td>
<td>10VRMS</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Superior to RS485 in most application environments
Superior to RS485
Dramatically superior to RS485
## Pyxos IC Immunity and ESD Test Results

<table>
<thead>
<tr>
<th>Test</th>
<th>Transformer-Isolated</th>
<th>Non-Isolated</th>
<th>Direct Connect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Device GND is Earth Grounded</td>
<td>Device GND Floating</td>
</tr>
<tr>
<td>EN 61000-4-2 ESD</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>EN 61000-4-3 Radiated RF</td>
<td>10V/m (Level 3)</td>
<td>10V/m (Level 3)</td>
<td>10V/m (Level 3)</td>
</tr>
<tr>
<td>EN 61000-4-4 Network Burst</td>
<td>2kV (Level 4)</td>
<td>2kV (Level 4)</td>
<td>2kV (Level 4)</td>
</tr>
<tr>
<td>EN 61000-4-5 Network Surge</td>
<td>2kV (Level 3)</td>
<td>2kV (Level 3)</td>
<td>2kV (Level 3)</td>
</tr>
<tr>
<td>EN 61000-4-6 Conducted RF</td>
<td>10Vrms (Level 3)</td>
<td>1Vrms (Level 1)</td>
<td>3Vrms (Level 2)</td>
</tr>
<tr>
<td>CISPR 22 Radiated EMI</td>
<td>Level A</td>
<td>Level A</td>
<td>Level A</td>
</tr>
</tbody>
</table>
Immunity & EMI Test Summary

- Transformer-Isolated devices are the most robust
- Lower-cost Non-Isolated devices are robust enough for many applications, and have better 60Hz common-mode noise rejection than most RS-485 transceivers
- The immunity of Non-Isolated devices is improved by floating the device’s logic ground with respect to Earth ground
Pyxos Network Variables (PNVs)

- Network data is passed using Pyxos Network Variables
- Each Pyxos Network Variable has
  - Direction
  - Size
  - Format
- PNVs defined by the Point
  - The collection of PNVs defines a Point’s interface
  - Point sends output variables to Pilot
  - Pilot updates input variable on Points
- Each Point can have up to 128 PNVs of four bytes each or longer PNVs with proportionate reduction in # of PNVs
Uses rich set of standard data types defined by LonMark® and Echelon
- Builds on wealth of extensive work
  - Standard Network Variable Types (SNVTs)
  - Standard Enumerations and Language Strings
- Standard definitions represent the wide variety of data types used in control systems

Manufacturers can provide standard descriptions of their devices defining their interfaces for use by other manufacturers' devices
- Expands the applicability of products to a bigger ecosystem
Point Registration Overview

- Registration is the process of assigning every point a slot and informing the pilot what points are present

- Every Point must be assigned a unique slot
  - Slot numbered 0 – 31

- Registration uses a combination of:
  - Pyxos chip built-in protocol
  - API firmware available from Echelon
  - Host Application Code

- Uses factory assigned UID
  - 48 bit unique ID

- Uses User assigned PID
  - A 64 bit program ID identifies what kind of node it is
    - Unhosted nodes all have zeros for the program ID
## Point Registration Schemes

- **Auto**
  - Pilot assigns unique slot to point
  - Hosted points
  - No user intervention

- **Manual**
  - Pilot assigns slot to point
  - Must be used for unhosted points
  - Multiple points can have same PID
  - User intervenes
    - to help identify points

- **Hardwired**
  - Point assigns itself a unique slot
    - Hosted points have preassigned slots
  - Pilot must know about it
  - No user intervention

Auto and Hardwired registration create truly self-organizing network
Pyxos System Design

- **Pilot**
  - Designed for a particular type application
  - Knows the types of Points in the system
    - How to register them
    - How they interact

- **Points**
  - Send data to Pilot and receive data from Pilot
  - No system knowledge
  - May be used in many types of applications
Pyxos System Design Tradeoffs

- **Closed/Open**
  - Closed systems may be simpler to design
  - Open systems benefit from volume of third party components

- **Static/Dynamic**
  - Dynamic systems allow for use in more applications
    - Varying number of Points of each type
    - Richer set of operations
    - User intensive setup/registration
  - Static systems allow for easier setup
    - No user interaction required
    - Difficult to expand
Product Offering

- **Pyxos FT Network Chip**
- **Pyxos EVK Evaluation Kit**
  - Reference designs and Functioning Evaluation boards
    - Pyxos Points (Nano, Sensor, Actuator), Pyxos Pilot Nodes and Link Power Supply
  - Pyxos Pilot & Pyxos Point API software
    - Pyxos Point API for a host processor
    - Pyxos Pilot API for a host processor
  - Development tools
    - Example Application code
    - Pyxos Application Configuration Utility
Pyxos EVK Overview

- **Pyxos Pilot** (ARM7 Host)
- **Pyxos Point Nano** (No Host)
- **Pyxos Point Sensor** (Tiny13 Host)
- **Pyxos Point Actuator** (ARM Host)

Optional LONWORKS USB Adapter (not provided with EVK)

LONWORKS TP/FT-10 Channel

USB (cable)
Pyxos EVK Highlights

- **Create & demonstrate**
  - Simple standalone Pyxos networks
  - Easy integration to LONWORKS networks

- **Demonstration of specific capabilities**
  - Deterministic response time for each Pyxos Point
  - Automatic binding of Pyxos network variables
  - Monitoring and control of Pyxos Points
  - Easy LONWORKS integration
  - Ease of installation methodology (Hardwired, automatic & plug-press-and-play)

- **Secure network access**
  - Detection of new, removed, or failed Pyxos Points
Application Development (contd.)

- **Source code (ANSI C) provided for**
  - Pyxos EVK application
    - Pilot – Room controller
    - Point – Sensor and actuator
  - Pyxos API
    - Only Platform.h needs to be updated for platform dependent data type definitions
  - SPI serial driver

- **Platform used**
  - Pilot (and Actuator Hosted Point) – Atmel ARM7
  - Sensor Point – Atmel AVR Tiny 13

- **New application development**
  - Update source code for new platform (all highlighted yellow)
  - Update application code for new application
  - Compile the code for new platform
Extending Beyond Pyxos Networks

- Multiple machines with Pyxos embedded networks are aggregated using a LONWORKS control network

Seamless integration with LONWORKS
- Both Pyxos and LONWORKS use same standard data type definitions
Leverage the LONWORKS Platform to Add Sophisticated Features

- Sophisticated systems can be engineered using an LNS® based tool such as the LonMaker® Integration Tool.
Pyxos & LonWORKS
A Complete Control Ecosystem

- Interface with the Internet and beyond using the Pyxos and LonWORKS platforms

Network Operations Center
Central Data Management Systems

INTERNET

i.LON 100

LonWORKS Control Network
Pyxos Embedded Control Network

Legend

Pyxos Room
Pyxos Machine
LonWORKS Device

ECHELON
Pyxos FT
Features Comparison with Other Technologies
Key Benefits

- **Pyxos chip includes protocol**
  - Most competing technologies leave the burden of protocol development to developer (RS-485, CAN, Zigbee)

- **Robust communication built into**
  - Physical layer
    - High common mode noise rejection and interference immunity
    - High ESD and electrical disturbances immunity
  - Higher layers
    - Forward Error Correction of up to 2 bits; 18 bit CRC error detection
    - Fully acknowledged transactions with automatic retries

- **Self-organizing**
  - Automatic and hardwired registration modes represent truly self-organizing network

- **Cost-effective**
  - Unhosted Points provide digital I/Os without the use of a host microcontroller
  - Hosted Points and Pilot provide complete flexibility to chose any microcontroller based on application requirement
## Technology Comparisons

<table>
<thead>
<tr>
<th>Feature</th>
<th>Pyxos</th>
<th>CAN</th>
<th>AS-I</th>
<th>LIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-organizing network * (Left as an exercise for the developer)</td>
<td>✓</td>
<td>✗*</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Deterministic operation * (Unbounded latency for messages with the same arbitration preamble)</td>
<td>✓</td>
<td>✗*</td>
<td>✓</td>
<td>✓*</td>
</tr>
<tr>
<td>High-speed signaling · (19.2kbps maximum)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✗*</td>
</tr>
<tr>
<td>≤25ms response time</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>Direct digital I/O without a microcontroller · (Requires either an integrated or external microcontroller)</td>
<td>✓</td>
<td>✗*</td>
<td>✓</td>
<td>✗*</td>
</tr>
<tr>
<td>Designed for multiple media · (Other media require gateways or additional modem IC)</td>
<td>✓</td>
<td>✗*</td>
<td>✗</td>
<td>✗*</td>
</tr>
<tr>
<td>Free topology wiring up to 100 meters, bus topology 400 meters</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>High common mode immunity * (Requires external isolation components at added cost)</td>
<td>✓</td>
<td>✗*</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>Power and data combined on polarity-insensitive wire pair · (Wiring is polarity-sensitive and relies on cable profile and connectors to avoid miswiring)</td>
<td>✓</td>
<td>✗</td>
<td>✗*</td>
<td>✗</td>
</tr>
<tr>
<td>18-bit packet cyclic redundancy check (CRC) · (One byte checksum) ****(Parity)</td>
<td>✓</td>
<td>✓</td>
<td>✗*</td>
<td>✗*</td>
</tr>
<tr>
<td>Automatic retry on CRC error · (Messages may be lost without detection)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✗*</td>
</tr>
<tr>
<td>Open API for Pilot / controller interoperability · (Varies by supplier - different implementations are not interoperable )</td>
<td>✓</td>
<td>✗*</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>Seamless interface to LONWORKS networks</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Internet options including tunneling and SOAP/XML messaging</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Feature</td>
<td>Pyxos</td>
<td>DALI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>-------</td>
<td>-------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-organizing network * (Requires a network manager and network database to configure the network and make changes)</td>
<td>✔</td>
<td>❌*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deterministic operation * (Unbounded latency for messages with the same arbitration preamble)</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High-speed signaling * (1.2kbps maximum)</td>
<td>✔</td>
<td>❌*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤25ms response time</td>
<td>✔</td>
<td>✗</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct digital I/O without a microcontroller * (All DALI nodes require a microcontroller)</td>
<td>✔</td>
<td>❌*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Designed for multiple media</td>
<td>✔</td>
<td>✗</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bus topology 400 meters * (300 meter maximum total wire)</td>
<td>✔</td>
<td>❌*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High common mode immunity * (Subject to significant noise issues especially at longer distances)</td>
<td>✔</td>
<td>❌*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power and data combined on polarity-insensitive wire pair</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-bit packet cyclic redundancy check (CRC)</td>
<td>✔</td>
<td>✗</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low cost nodes</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seamless interface to LONWORKS networks * (DALI networks are not extendable – they require a gateway into BAS systems or once the maximum number of nodes has been reached)</td>
<td>✔</td>
<td>✗</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internet options including tunneling and SOAP/XML messaging * (There is no DALI infrastructure for interfacing with the Internet or Web services based applications)</td>
<td>✔</td>
<td>✗</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Technology Comparisons (cont’d)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Pyxos</th>
<th>Zigbee</th>
<th>Z-Wave</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-cost node</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Self-organizing network</td>
<td>✔</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Robust communication in the face of noise and impairments</td>
<td>✔</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Designed for multiple media</td>
<td>✔</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Interoperable hybrid wired and wireless networks</td>
<td>✔</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Open standard protocol between devices</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Open standard protocol between Pilot / controllers</td>
<td>✔</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>Open Pilot / controller API</td>
<td>✔</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Standardized object models</td>
<td>✔</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Ecosystem for small and large system architectures</td>
<td>✔</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Seamless interface to LONWORKS networks</td>
<td>✔</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Internet options including SOAP/XML</td>
<td>✔</td>
<td>✔</td>
<td>✗</td>
</tr>
</tbody>
</table>
## Technology Comparisons (cont’d)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Pyxos</th>
<th>RS-485</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-organizing network</td>
<td>✓</td>
<td>Protocol not included; depends on which protocol used</td>
</tr>
<tr>
<td>Deterministic operation</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>≤25ms response time</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>High-speed signaling</td>
<td>✓</td>
<td>Variable</td>
</tr>
<tr>
<td>Direct digital I/O without a microcontroller</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>Bus topology distance</td>
<td>✓</td>
<td>Variable Distance</td>
</tr>
<tr>
<td>Free topology</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>High common mode immunity * (three out of four coupling options provide same or better common mode noise rejection)</td>
<td>✓*</td>
<td>Variable dependent on how expensive RS-485 used</td>
</tr>
<tr>
<td>Power and data combined on polarity-insensitive wire pair</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>18-bit packet cyclic redundancy check (CRC)</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>Error Correction for up to 2-bit errors per packet</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>Low cost nodes</td>
<td>✓</td>
<td>Variable</td>
</tr>
<tr>
<td>Simple interface to LONWORKS networks</td>
<td>✓</td>
<td>✗</td>
</tr>
</tbody>
</table>
Technology Comparisons

Pyxos Networks Price/Performance Advantage

<table>
<thead>
<tr>
<th>Network Throughput</th>
<th>Relative Cost / Node</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5 kbit/s</td>
<td>Very-Low 1</td>
</tr>
<tr>
<td>50 kbit/s</td>
<td>Low 2</td>
</tr>
<tr>
<td>100 kbit/s</td>
<td>Medium 3</td>
</tr>
<tr>
<td>500 kbit/s</td>
<td>High 4</td>
</tr>
<tr>
<td>&gt;1 Mbit/s</td>
<td></td>
</tr>
</tbody>
</table>

CAN

PYXOS

DALI
Technology Comparison

**Pyxos vs. Controller Area Network (CAN)**

<table>
<thead>
<tr>
<th>Throughput</th>
<th>40 meters</th>
<th>100 meters</th>
<th>200 meters</th>
<th>500 meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 kbit/s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 kbit/s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500 kbit/s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very-High</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Mbit/s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- CAN - Performance degrades with bus length
- Performance Advantage
- Constant performance as bus length increases
Summary

- Pyxos networks uniquely meet the needs of sensor and I/O networks
  - Extending control applications
  - Embedded control inside machines

- Pyxos networks are
  - Deterministic (less than 25ms response time)
  - High Speed (312.5kbps)
  - Highly robust
    - Forward error correction and 18 bit CRC error detection
    - Exceptionally high common mode and magnetic noise immunity
  - Self-organizing

- Pyxos network communication chip
  - Includes protocol
  - Is very inexpensive