



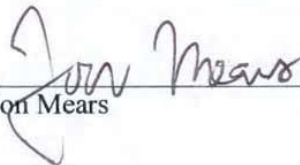
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# Embedded Systems

R O G R A M M I N G

## Ada Achieves Orbit

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Cruising with Ada  
Basics of Networking  
Containers in C++  
Plauger on Prediction



## A Satellite Case Study

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BY RICHARD RIEHLE. Like C++ before it, Ada is leaving criticisms behind and finding acceptance in a variety of embedded applications. This case study recalls the trials and triumphs of a satellite design team's decision to shift to Ada.



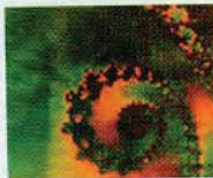
### 18 Cruising with Ada

BY DO-WHILE JONES. Too many developers let their tools dictate their designs. In this system design manifesto, Jones looks at the dangers of inappropriate design methodologies and the advantages of Ada as a prototyping tool for a typical microcontroller application.



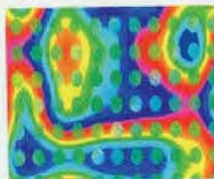
### 46 Communication Protocols for Embedded Systems

BY BHARGAV UPENDER AND PHILIP KOOPMAN. Some networking architectures were designed without embedded or real-time concerns in mind. Here's an overview of the tradeoffs in choosing different embedded networking protocols.



### 60 Containers and Templates

BY BRUCE ECKEL. Container classes are quite useful. Implementing them, however, often requires template support. In keeping with our emphasis on "under the hood" details, this month's introduction to C++ containers is also an exploration in the use of templates.



## ON THE COVER:

If your geosynchronous service calls are getting too expensive, try shifting to Ada. Cover by Rupert Adley.

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by BHARGAV UPENDER and PHILIP KOOPMAN

# Communication Protocols for Embedded Systems

There's more to connecting multiple CPUs than just stringing wires or cable. Your choice of network protocol, in particular, will determine system performance.

The past few years have seen a growing trend to dramatically increase the embedded electronics content of automobiles, elevators, building climate control systems, jet aircraft engines, and other traditionally electro-mechanically controlled systems. In many large systems, this increasing electronics content is accompanied by a proliferation of subsystems with separate CPUs.

The increase in the number of processors in a system is often driven by computation and I/O growth. In some development environments, the increase may also be driven by a need to ease system integration burdens among multiple design groups or to provide system flexibility through "smart sensors" and "smart actuators." Whatever the reasons, once there is more than one CPU in a system, there must be some means of communication to coordinate action.

While some high-end embedded systems communicate over a VME backplane or similar arrangement, the embedded systems we're working on use physically distributed CPUs involving some sort of local area network (LAN), also called a multiplexed network or a communication bus. At the heart of the LAN is the media access protocol, which picks the next

transmitter for access to the shared network medium, typically a wire, fiber, or RF frequency.

In this article, we will discuss the special considerations for networking real-time embedded systems, and look at several media access protocols that demonstrate fundamentally different ways of accessing the shared medium. The protocols are: connection-oriented protocols, polling, time division multiple access (TDMA), token ring, token bus, binary countdown, carrier sense multiple access with collision detection (CSMA/CD), and carrier sense multiple access with collision avoidance (CSMA/CA). For each of these, we will evaluate the strengths and weaknesses against special considerations. A protocol tradeoff chart will enable you to select a protocol to fit your needs. While no protocol is perfect for all purposes, a variation of CSMA/CA offers the most versatility for many embedded systems.<sup>1</sup>

## SPECIAL CONSIDERATIONS

In practice, we have found that embedded real-time networks require high efficiency, deterministic latency, operational robustness, configuration flexibility, and low cost per node.

Because cost limits the network bandwidth available to many applica-

Nancy Paternoster

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