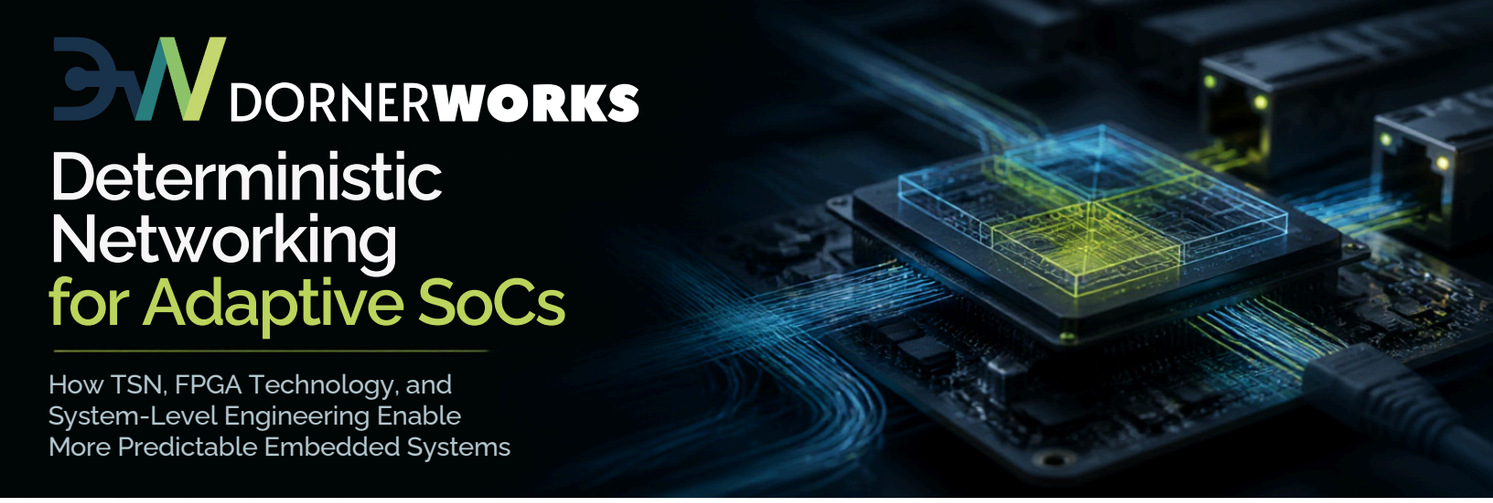

Deterministic Networking on AMD Versal™ Adaptive SoCs

Integrating Time-Sensitive Networking, FPGA Technology, and Embedded Processing for Predictable System Communication

Introduction: The Challenge of Connected Embedded Systems

As embedded systems demand higher data throughput, precise timing, and increasingly complex processing, integrating networking and programmable logic has become an important system design consideration.

Applications in aerospace, defense, industrial automation, and advanced sensing increasingly depend on multiple subsystems communicating within defined timing requirements. In these environments, network delays, congestion, and unpredictable data delivery can affect overall system performance.

AMD Versal™ Adaptive SoC devices bring together processing resources, programmable logic, and high-speed connectivity, giving engineers flexibility to develop architectures that address these demands.

Combined with Time-Sensitive Networking (TSN), these capabilities create opportunities to design more predictable, synchronized communication across connected embedded systems. Realizing that potential requires thoughtful integration of FPGA logic, networking interfaces, embedded software, and system-level timing requirements.

When considered alongside FPGA technology and Adaptive SoC architectures, TSN becomes part of a broader engineering conversation: how to integrate networking, processing, and application-specific functionality into increasingly complex embedded systems.

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1. AMD Versal™ Adaptive SoCs: Bringing Processing, Programmable Logic, and Connectivity Together

As embedded applications become more computationally demanding and

network speeds continue to increase, engineers are looking for architectures that bring processing resources, programmable logic, and high-speed connectivity together.

AMD Versal™ Adaptive SoC devices provide an adaptable architecture for this type of system design. By combining processing capabilities with programmable logic and integrated connectivity, Versal platforms give engineering teams flexibility in determining how application processing, specialized data paths, and system communication are implemented.

For systems incorporating Time-Sensitive Networking, this flexibility creates opportunities to coordinate networking functions with application-specific hardware and embedded software.

Supporting Higher Network Speeds

As embedded networks evolve from 1 Gigabit Ethernet (GbE) toward 10 GbE and beyond, handling increasing data rates becomes an important architectural consideration. FPGA technology can support high-throughput networking interfaces and custom data paths, helping engineers adapt processing and connectivity to application-specific bandwidth requirements.

Depending on the platform and implementation, programmable logic can also support efficient data movement and processing without relying exclusively on software-based processing paths.

Enabling Low-Latency Communication

TSN applications often depend on precise timing and synchronization across networked devices. FPGA-based implementations can support low-latency hardware data paths and precise hardware timestamping, helping reduce processing delays and variability that can affect time-sensitive communication.

Achieving the required synchronization performance also depends on the complete network architecture, clock synchronization mechanisms, and endpoint implementation.

Integrating Networking and Processing

In a TSN-enabled system, networking cannot be considered in isolation. Engineers must determine how networking interfaces interact with processing resources, where application-specific logic is needed, and how communication functions integrate with embedded software.

FPGA and programmable logic resources may support high-speed interfaces, specialized data paths, and time-critical processing, while processing resources support software execution, configuration, and system control. The right implementation depends on the selected platform, networking architecture, and application requirements.

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2. Understanding Time-Sensitive Networking

With the processing and programmable logic capabilities of Adaptive SoCs

providing a flexible hardware foundation, the next consideration is how data moves between connected devices.

Time-Sensitive Networking extends standard Ethernet capabilities to support applications that require coordinated communication and predictable traffic delivery. Rather than replacing Ethernet, TSN introduces mechanisms that help manage how data moves across a network.

Key capabilities include:

- **Time synchronization:** Establishing a shared time reference across networked devices.
- **Traffic scheduling:** Coordinating transmission opportunities for time-sensitive data.
- **Traffic prioritization:** Managing different classes of network traffic according to application requirements.
- **Traffic policing:** Helping prevent improperly behaving traffic from disrupting other network streams.

IEEE standards such as 802.1AS, 802.1Qbv, and 802.1Qci provide mechanisms supporting these capabilities.

Together, these technologies give engineers additional tools for designing Ethernet networks that support both time-sensitive and conventional data traffic.

However, implementing TSN requires more than confi guring individual network features. Engineers must consider synchronization, endpoint behavior, network topology, traffic characteristics, and system-level performance requirements.

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3. Engineering for Deterministic Communication

Predictable communication requires a coordinated approach across the network and the connected devices.

Several engineering considerations influence the final implementation:

Synchronization and timing

Networked devices must maintain appropriate time synchronization to support coordinated communication. Engineers must understand synchronization requirements, timing accuracy, and how clock behavior affects the overall architecture.

Traffic management

Different data streams have different bandwidth, latency, and priority requirements. Network configuration must account for these differences while managing competing traffic.

Hardware and software integration

Networking capabilities must work alongside application processing, device interfaces, embedded software, and system control functions.

System-level validation

Individual components may perform as expected in isolation but behave differently when integrated. Testing must account for realistic traffic patterns, system workloads, and operating conditions.

These considerations highlight why deterministic networking is fundamentally a system engineering challenge, not simply a networking configuration exercise.

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4. From Development Platform to System Implementation

Development platforms and reference designs provide engineers with a practical starting point for exploring Adaptive SoC architectures, evaluating networking capabilities, and testing implementation approaches before committing to a complete system design.

For AMD Versal™ platforms, this process allows engineering teams to investigate how processing resources, programmable logic, and networking interfaces can work together to address application-specific requirements.

A development platform is a foundation, not a finished system. Moving from an initial implementation toward deployment may require adapting hardware interfaces, integrating embedded software, configuring network behavior, refining processing architecture, and validating performance under representative operating conditions.

The objective is to understand which capabilities can be reused, which require customization, and how the complete system will perform within its intended application.

Successful integration also requires system-level validation**.** Individual components may perform as expected in isolation but behave differently once connected. Testing must account for realistic traffic patterns, system workloads, synchronization requirements, and operating conditions.

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5. Bringing Adaptive SoC Designs Together

Designing embedded systems around Adaptive SoC architectures requires more than expertise in programmable logic or networking alone. It requires an understanding of how hardware, software, processing, and communication work together across the complete system.

From evaluating an architecture and developing an initial prototype to integrating specialized functionality and validating system behavior, each stage brings its own engineering considerations.

DornerWorks brings together FPGA, embedded hardware, software, and networking expertise to help engineering teams navigate these challenges. Our system-level approach helps bridge the gap between individual technologies and integrated systems designed around real-world application requirements.

As AMD Versal™ Adaptive SoCs enable increasingly flexible embedded architectures, thoughtful design and integration remain essential to turning that flexibility into working systems.

Whether evaluating an architecture, developing a prototype, or integrating specialized functionality into an existing platform, we help engineering teams address the technical challenges that exist between individual components and a working system.

Conclusion: Designing for the Complete System

As connected embedded systems continue to evolve, deterministic networking will remain an important consideration for applications that depend on coordinated communication and predictable data movement.

TSN provides standardized mechanisms for managing time-sensitive Ethernet traffic. FPGA technology and Adaptive SoC architectures offer additional fl exibility for integrating specialized processing and system functionality.

Realizing the benefi ts of these technologies requires an understanding of how networking, hardware, and software interact across the complete system.

DornerWorks helps engineering teams bridge those disciplines, bringing together embedded systems expertise, FPGA development, and networking capabilities to address complex engineering requirements.

For more information, visit DornerWorks.com or contact our sales team at sales@DornerWorks.com.