Scalable On-Device Management and High Availability Middleware for Embedded and Emerging Cloud-Based Systems

All complex software based embedded systems need a middleware software framework that delivers manageability, high availability, and robustness. The middleware requirements range from simple system level communication and debug, to system HW/SW health monitoring, to support for external operations management systems, and up to high availability and/or robust fault management. The middleware must also support a wide range of HW platforms from simple SoCs, single boards, big chassis-based systems, rack mount servers, and emerging Cloud-based platforms.

Enea Element is a high-availability middleware package that provides a suite of embedded application development services for mission critical applications requiring event-driven real-time response, fault tolerance, model-based management for configuration and monitoring, and the highest levels of performance and scalability. Enea Element’s SAF standards-based services integrate with a wide variety of COTS hardware - from single SoC, to single board, to simple clusters, to chassis based systems (Micro uTCA or ATCA), rack mount servers, and to Cloud platforms (including Amazon EC2) - providing a flexible application-ready computing platform.

Modular, Flexible Architecture
Enea Element’s middleware services provide the modularity and flexibility needed to accommodate a wide range of equipment and applications. The full suite of services is ideal for implementing networking infrastructure such as base stations, media gateways, storage switches, IP routers/switches, CMTS (cable modem termination system), etc. However, Enea Element is not an “all or nothing” proposition. Its modular architecture allows a subset of its services to be deployed in simple designs or in cases where the vendor just wants to enhance its own legacy infrastructure services.

Enea Element is a layered set of Frameworks, each adding more capability. The base layer is the Distributed System Framework (DSF) which includes the Messaging and Clustering Services, the Logging Service,
and a Runtime Debug Service called the Command Service. The DSF provides the necessary functionality to develop, integrate, and deploy flexible distributed applications. The next layer, the Embedded Management Framework (EMF), adds model-based embedded system management. The top layer, the High Availability Framework (HAF), rounds out Enea Element. The HAF adds services for fault management and in-service software upgrade to deliver non-stop service availability in the face of hardware and software errors as well as planned maintenance and product evolution.

The DSF, EMF, and HAF services provide a solid foundation for building systems that require real-time determinism, reliable operation, and the scalability and survivability of a distributed system. This makes Enea Element, in addition to networking infrastructure, a good fit for military/aerospace, medical, industrial, and many emerging M2M applications. In cases where HA is not required, the DSF and EMF provide a solid programming foundation without the burden of a complex HA framework. See Figure 1 for a depiction of Element modular offerings.

Standards-Based, Portable, and Scalable
The open standards-based development model gives system vendors the flexibility to choose components and protects them from proprietary vendor lock-in. Designed as a multi-platform service suite, Enea Element runs on a wide array of heterogeneous hardware platforms (ATCA, MicroTCA, IBM Blade Center, x86, PPC…), cloud platforms (from public clouds like EC2 to private clouds), and operating systems (Linux, RTOS, DSP executives, etc). This versatility, coupled with its inherent portability, insulates applications from changes in the hardware and OS layers, thereby increasing application portability and code re-use. This versatility also makes it easier for equipment makers to leverage technology advancements in the underlying platform without compromising their huge investment in application software.

To further enhance portability and interoperability, Enea provides support for Service Availability Forum (SAF) standards for Hardware Platform Interface (HPI) and Application Interface Specification (AIS).

Designed for Distributed, High Performance, and Scalable Systems.
Enea Element’s real-time services are optimized for demanding distributed applications that require the utmost in performance and scalability. Unlike competitive middleware solutions, the services are implemented as a native lightweight framework (not an extra “kernel emulation” layer), which leverages a standard set of OS capabilities to provide a low-overhead execution environment. This native design utilizes the inherent features of the OS and ensures that vendors’ applications are not locked into a proprietary execution model. Element leverages Enea’s heritage as a leader in distributed, high-availability applications, building on and extending field-proven Enea LINX message passing technology. Deployed in some of the world’s most

![Figure 1 – Modularity - Element is a layered, modular, standards-based architecture supporting a wide variety of hardware platforms and operating systems](image-url)
advanced 3G and 4G wireless and wire line applications, Enea LINX provides a complete, multi-platform, open source IPC (inter-process communication) service for distributed applications, complete with sophisticated discovery, supervision, and addressing capabilities.

Enea LINX and Enea Element provide a scalable solution that can be readily deployed on a wide range of systems, from a single node on a single blade, to large-scale distributed systems spanning hundreds of nodes, blades and shelves. Enea Element’s small footprint and support for DSPs also enables it to scale down to deeply embedded systems. This versatility and scalability reduces development time and cost by enabling equipment makers to maintain a single code base across a broad range of applications and hardware platforms.

**Continuous Availability**
The need for always on, self-healing operation is becoming a standard requirement in many applications. Increasingly, systems must be able to run continuously and recover from failures without disrupting service to end users. To meet this requirement, Enea provides a high-availability framework that greatly enhances system monitoring, fault detection, and recovery.

Enea Element’s distributed architecture with service-centric discovery and supervision and memory protected modules isolates faults and minimizes their effect on system operation. Building on this secure foundation, the HA manager provides rapid fault detection, recovery, and reporting services. It also manages overall system state, promotes service mobility, and orchestrates recovery actions based on the best available redundancy options. A lightweight check-pointing service supports critical data replication, so applications can pick up where they left off after a failure. The HA manager is conformant to the Service Availability Forum (SAF) Availability Management Framework (AMF) that provides a rich set of redundancy models (2N or 1:1, N+M, N-Way, and N-Way Active) as well as flexible failover configurations where active and standby components may reside on the same or different nodes. See Figure 2 for a depiction of these redundancy models.

**Software Management - In-Service Upgrade**

![Figure 2 – Element AMF Redundancy Models](image)
In-Service Upgrade is a vital part of any solution where “cold” system upgrades equate to a significant device failure and, therefore, “down time.” Enea Element’s In-Service Upgrade Manager supports both individual component and node-level upgrade steps within a running cluster with no service impact. It uses the HA services to coordinate failover and/or restarts of components to best accommodate the restart of software from old to new versions. Multiple components can be upgraded in a carefully controlled sequence to allow each upgrade step to achieve a state of “service readiness,” indicating that the software is ready to progress from an upgrade state before the next step is executed. This provides a progression through system/node/component software upgrade that maintains service availability throughout. Since programming interfaces and management data are expected to change from one release of applications to the next, mechanisms are provided from the underlying messaging services up through the upgrade service to support forward and backward compatibility. See Figure 3.

Figure 3, Element In-Service Upgrade
On-Device Management

Enea® Element provides a full-featured service for model-based management of embedded systems allowing managing entities to perform model-based dynamic and offline configuration and monitoring of state and status. In addition, a managing entity can invoke modeled system-wide actions and receive asynchronous modeled notifications from the embedded system. The model-based service uses the standards-based YANG modeling language for describing the management model for the embedded system. A standardized NETCONF interface that provides an advanced framework for managing and supervising the configuration of a network device. A model-driven Command Line Interpreter (CLI) supports direct user management of the embedded system and an XML-RPC Server interface allows protocol-based management by software-based management systems such as an EMS, NMS, or OSS. An SNMP interface provides read access to managed objects via the SNMP protocol. A common interface between the internal object manager and the northbound agents isolates the details of the management interface from the Southbound API used by the embedded software applications within the managed system. The Southbound API provides fully distributed access to the embedded software allowing applications to register, with fully granular scope, for updates to configuration managed objects and to register for operational data managed objects provided by the application when requested by Northbound clients.

The embedded object manager supports multiple northbound management sessions and implements transactions with ACID properties and full rollback support as far as 100 transactions. As with all services within Element, the Embedded Management Service is fully redundant and is integrated with the In-Service Upgrade Manager to facilitate configuration migration, including schema migration encountered during a software upgrade. See Figure 4.
Enea® Element™

**Distributed Systems Framework**
- Publish/Subscribe and flow control messaging models simplify the task of building carrier-grade applications.
- Distributed, redundant event log delivers a single, time-synchronized event trace for the entire distributed system. Flexible filtering and storage options enable pinpoint error detection.
- Distributed, dynamic system monitor provides run-time visibility into internal implementation-specific status and behavior.
- Operating system and Hardware platform abstraction layers facilitate porting to various operating systems, CPUs and chassis or cloud architectures.

**On-Device Management**
- System configuration and data model driven from modular YANG source model (IETF RFC 6020).
- ACID transactions with a redundant configuration data store, support for rollback of up to N transactions (default, N=100). Support for multiple transaction types, including exclusive, private, and shared transactions.
- Support for AAA -authentication, authorization, and accounting/auditing.
- Southbound API supports distributed dynamic registration for configuration validation and updates as well as to provide operational data objects upon request by northbound clients.
- NETCONF support provides configuration transactions and validations, notification streams, and selective data retrieval over a secure channel.
- Model-driven CLI supports full navigation through both status and configuration managed objects.
- SNMP support allows read access to managed objects and support for generation of SNMP traps.
- XML-RPC server support for XML-based clients allows access to transactions, actions, schema query, and configuration data store management.

**High Availability Framework**
- Application, node and system level availability manager provides application loading and active fault monitoring, detection, recovery, and notification services.
- System modeling with flexible, user-defined, policy-based fault handling capability.
- SAF-AMF conformance for flexible redundancy models – 1:1, 1:N, N+M, 2N, N-way, and N-way Active.
- Lightweight, high performance checkpointing service supports replication of critical application data to a backup instance.
- In-service upgrade manager leverages availability management services to deliver true hot upgrade/downgrade on mission critical systems.
- API version management toolkit helps developers build change-tolerant APIs for backwards compatibility with older versions, making in-service upgrades smoother.

**Specifications**

**Development Hosts**
- RHEL 6 (RedHat Enterprise Linux)
- Centos 6.3, 6.4
- Ubuntu 12.04 LTS

**Targets**
- RHEL 6 (RedHat Enterprise Linux) Centos 6.3, 6.4, 6.5
- Ubuntu 12.04 LTS, 13.10
- Enea Linux 3.1
- MontaVista Linux CGE 6.0
- Other Linux distributions on request

**Supported CPUs:**
- Intel Architecture (x86, x86_64 and compatibles)
- MIPS64/Cavium
- PowerPC
- ARM

**Supported Languages:**
- C and C++
- Java
- Python

**Other**
- Support for OpenHPI 3.2.0
- Support for deployment on the Amazon EC2 (Elastic Compute Cloud)

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Enea is a global software and services company focused on solutions for communication-driven products. With 40 years of experience Enea is a world leader in the development of software platforms with extreme demands on high-availability and performance. Enea's expertise in realtime operating systems and high availability middleware shortens development cycles, brings down product costs and increases system reliability. Enea's vertical solutions cover telecom handsets and infrastructure, medtech, industrial automation, automotive and mil/aero. Enea has 750 employees and is listed on Nasdaq OMX Nordic Exchange Stockholm AB. For more information please visit enea.com or contact us at info@enea.com.

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