The MILS Partitioning Communication System + RT CORBA = Secure Communications for SBC Systems

Kevin Buesing
Objective Interface Systems
kevin.buesing@ois.com

Jeff Chilton
Objective Interface Systems
jeff.chilton@ois.com

This presentation represents joint research between the Air Force, Army, Navy, NSA, Boeing, Lockheed Martin, Objective Interface, Green Hills, Lynux Works, Wind River, GD, Rockwell Collins, MITRE, U of Idaho
Foundational Threats

Wild Creatures of the Net, Worms, Virus, . . .
Foundational Threats
(That MILS Protects Against)

Under MILS Network Data and Privilege Mode Processing is Separated
Are your avionics ready for the Global Information Grid?
MILS Overview
The Whole Point of MILS

Really simple:

• Dramatically **increase the scrutiny** of *security critical code*

• Dramatically **reduce the amount** of *security critical code*
What does MILS do?

Enable the Application Layer Entities to Enforce, Manage, and Control

**Application Level Security Policies**

in such a manner that the Application Level Security Policies are

- **Non-bypassable**
- **Evaluable**
- **Always-Invoked**
- **Tamper-proof**

MILS = Multiple Independent Levels of Security/Safety
How does MILS achieve its objectives?

Enforce an 

Information Flow, 
Data Isolation, 
Periods Processing, and 
Damage Limitation 

Security Policy 

between multiple address spaces:

First, in a **Microprocessor Centric Manner**, i.e., MILS RTOS Kernel, 
Second, in a **Network Centric Manner**, i.e., MILS Middleware, 

in such a manner that the layered Security Policies are

**NEAT**
Orange Book vs. MILS Architecture

Monolithic Applications

Middleware

Kernel

Damage Limitation

Periods Processing

Network I/O

Information Flow

Data isolation

Auditing

DAC

MAC

File systems

Device drivers

User Mode

Mathematical Verification/Evaluation

Privilege Mode

Device drivers

Network I/O

Data isolation

Auditing

DAC

MAC

File systems

9/16/2004

SBC 2004
Executive Overview
MILS Three Layer Architecture

Three distinct layers (John Rushby, PhD)

Partitioning Kernel
- Trusted to guarantee separation of time and space
  - Separate process spaces (partitions)
  - Time partitioning
- Secure transfer of control between partitions
- Really small: 4K lines of code

1. Middleware
- Secure application component creation
- Secure end-to-end inter-object message flow
- Most of the traditional operating system functionality
  - Device drivers, file systems, etc.
- Partitioning Communications System
  - Extends the policies of Partitioning Kernel to communication
  - Facilitates traditional middleware
    - Real-time CORBA, DDS, web services, etc.

2. Applications
- *Can* enforce application-specific security functions
- *e.g.*, firewalls, crypto services, guards
Layer Responsibilities

Partitioning Kernel Functionality
- Time and Space Partitioning
- Data Isolation
- Inter-partition Communication
- Periods Processing
- Minimum Interrupt Servicing
- Semaphores
- Timers
- Instrumentation

And nothing else!

MILS Middleware Functionality
- **RTOS Services**
  - Device Drivers
  - CORBA
  - File System
  - ...

- **Partitioned Communication System**
  - Inter-node communication
Executive Overview
MILS Architecture – High Assurance

Application (User Mode) Partitions

- MILS - Multiple Independent Levels of Security
- MSL - Multi Single Level
- MLS - Multi Level Secure
- SL - Single Level

RTOS Micro Kernel (MILS Partitioning Kernel)

Supervisor Mode
MMU, Inter-Partition Communications Interrupts

Processor

- S (SL)
- TS (SL)
- S,TS (MLS)

Run Time Libraries
RT CORBA

Keyboard Device Driver (MSL)
File Sys Device Driver (MSL)
Network Interface Unit (MSL)
PCS (MSL)
Partitioning Kernel: Just a Start …

- Partitioning Kernel provides
  - Secure foundation for secure middleware
- Secure Middleware provides
  - Most of traditional O/S capabilities
    - File system
    - Device drivers (*not* in the kernel, not special privileges)
    - Etc.
  - Secure intersystem communication (PCS)
  - Secure foundation for building secure applications
- Secure Applications can
  - Be built!
  - Be trusted to enforce application-level security policies!!!
Distributed Security
Distributed Security Requirements

• Rely upon partitioning kernel to enforce middleware security policies on a given node
  – Information Flow
  – Data Isolation
  – Periods Processing
  – Damage Limitation

• Application-specific security requirements
  – must not creep down into the middleware (or kernel)
  – ensure the system remains supportable and evaluatable

• Optimal inter-partition communication
  – Minimizing added latency (first byte)
  – Minimizing bandwidth reduction (per byte)

• Fault tolerance
  – Security infrastructure must have no single point of failure
  – Security infrastructure must support fault tolerant applications
Distributed Object Communication

- Partition Local – same address space, same machine
- Machine Local – different address space, same machine
- Remote – different address space, on a different machine
Partitioned Communication System
Partitioned Communication System

- Part of MILS Middleware
- Responsible for all communication between MILS nodes

Purpose
- Extend MILS partitioning kernel protection to multiple nodes

Similar philosophy to MILS Partitioning Kernel
- Minimalist: only what is needed to enforce end-to-end versions of policies
  - *End-to-end* Information Flow
  - *End-to-end* Data Isolation
  - *End-to-end* Periods Processing
  - *End-to-end* Damage Limitation

- Designed for EAL level 7 evaluation
PCS Objective

- Just like MILS Partitioning Kernel:
  - Enable the Application Layer Entities to
    - Enforce, Manage, and Control
  - Application Level
    - Security Policies
  - in such a manner that the Application Level Security Policies are
    - Non-Bypassable,
    - Evaluatable,
    - Always-Invoked, and
    - Tamper-proof.
  - An architecture that allows the Security Kernel and PCS to share the RESPONSIBILITY of Security with the Application.
- Extended:
  - To all inter-partition communication within a group of MILS nodes (enclave)
PCS Requirements

- Strong Identity
  - Nodes within enclave
- Separation of Levels/Communities of Interest
  - Need cryptographic separation
- Secure Configuration of all Nodes in Enclave
  - Federated information
  - Distributed (compared) vs. Centralized (signed)
- Secure Loading: signed partition images
- Suppression of Covert Channels
  - Bandwidth provisioning & partitioning
  - Network resources: bandwidth, hardware resources, buffers
Executive Overview
MILS Network Security Policy
Example

Policy Enforcement Independent of Node Boundaries

PCS Provides *End-to-End*:
- Information Flow
- Data Isolation
- Periods Processing
- Damage Limitation

Red Network

System

CPU & Network
Registers, Switches, DMA, …
MILS Replaces Physical Separation

- MILS architecture allows computer security measures to achieve the assurance levels as “physically isolated” systems
  - All O/S code not necessary for performing Partitioning
    Kernel functions moved out of privileged mode
  - O/S service code moved to middleware layer
    • e.g. device drivers, file system, POSIX
  - Prevents software and network attacks from elevating a partition privilege to an unauthorized level
Best Security/Safety is Physical (Air Gap)

Intranet
(Proprietary, Sensitive, Critical)

Processor R1
App

Processor R2
App

Processor Rn
App

Internet
(Public, Untrusted)

Processor B1
App

Processor B2
App

Processor Bn
App
Legacy Approach to Bridging the Air Gap
(Good, Expensive, Physical Solutions Exist)

Red
(classified, Sensitive, Critical)

- Very high assurance
- Off-the-shelf solution

Black
(unclassified, Public, Untrusted)

• One-Way Gate
• Write-Down Guard
• Office environment only
• Extra hardware

Processor R1
App

Processor R2
App

SNS

Processor Rn
App

Processor B1
App

Processor B2
App

Processor Bn
App

9/16/2004 SBC 2004
Air Gap Solution to SDR – Separate Hardware

This is current stovepipe technology that is expensive and inflexible.
A Simple Application of MILS to SDR – Separate Processor Resources

Modem

Crypto Engine

Red Processor

Modem

Crypto Engine

Red Processor

Modem

Crypto Engine

Red Processor

Channel A
(Top Secret)

Channel B
(Secret)

Channel C
(Confidential)

Channel D
(Unclassified)

Need MILS Solution Here!

Need MILS Solution Here!

Need MILS Non Real-Time Operating Environment Solution Here!

AND

AND
Multi-Level Secure/Safe (MLS): Processes data of differing classifications/sensitivities securely/safely
- down graders
- data fusion
- guards
- firewalls
- data bases

Multi-Single Level Secure/Safe (MSLS): Separates data of differing classifications/sensitivities securely/safely simultaneously
- communications platforms
- infrastructures
MILS Can Handle MLS

– A Partitioning Kernel is ignorant of traditional Multi-Level Security (MLS)
  • Requirement for military and intelligence systems
– However, MILS is quite capable of supporting MLS systems
– MILS can be used to construct MLS systems because of
  • Strong separation guarantees
  • Certification process
Applying MILS to Software Defined Radio
Example – JTRS
Joint Tactical Radio System

- Family of software programmable radios
- Design around Software Communications Architecture
- JTRS provides reliable multichannel voice, data, imagery, and video communications
- Eliminates communications problems of "stovepipe" legacy systems
- JTRS is:
  - Modular, enabling additional capabilities and features to be added to JTR sets
  - Scaleable, enabling additional capacity (bandwidth and channels) to be added to JTR sets
  - Backwards-compatible, communicates with legacy radios
  - Allowing dynamic intra-network and inter-network routing for data transport that is transparent to the radio operator
Designing an MLS Component

MLS Middleware Component

Ex: Cryptographic downgrader, such as JTRS or trusted network interface unit

Classified network (Red), labeled messages

Unclassified Network (Black)
Designing an MLS Component

Classified network (Red), labeled messages

Unclassified Network (Black)
Designing an MLS Component

Classified network (Red), labeled messages

Certified Downgrader

Unclassified Network (Black)

Single Level Components (MSL)
Designing an MLS Component

Certification Requirements:
Incoming messages will be encrypted with the specified algorithm and key
Output is strongly encrypted
Each device downgrades from one specific level to unclassified

Classified network (Red), labeled messages
Unclassified Network (Black)
Designing an MLS Component

Certification Requirements:
Messages from either side will maintain labels and contents
Periods processing (transaction based) unit
Designing an MLS Component

Certification Requirements:
- Messages from NIU will be routed to appropriate encryption unit
- Periods processing (transaction based) unit

Classified network (Red), labeled messages
Designing an MLS Component

Certification Requirements:
Messages from decryption units will be labeled correctly before sending to NIU
Periods processing (transaction based) unit

Classified network (Red), labeled messages

Unclassified Network (Black)
Designing an MLS Component

Black Communication Links
Certification Requirements:
Tamperproof, Non bypassable, Evaluatable

Red Communication Links
Certification Requirements:
Tamperproof, Non bypassable, Evaluatable

Classified network (Red), labeled messages

Unclassified Network (Black)
The MILS Architecture Approach

- Describe the system in terms of communicating components
  - Designate the clearance of each component and label as MLS or MSL
  - Determine the flow between components with respect to policy
  - Install “boundary firewalls” that manage information up-flow and down-flow
    - these are MLS components
The MILS Architecture Approach

• For each MLS device, determine its type
  – **Downgrader** – will take data from one security level and send data at a lower level
  – **Transaction processor** – will process data one message at a time; stateless, may filter data or perform operation on single message
  – **Collator** – will combine data from many inputs
• Verification of each device may involve additional MILS componentization
Implementation

• Hierarchical Approach
  – Lowest level is separation kernel – enforces isolation, information flow, periods process, damage limitation on a single processor
  – Next level is middleware, to coordinate end-to-end separation
    • Need to create “trusted” components.
      – Verification of the components utilizes architectural support of lower layer
  – Next Level is application specific
Acronyms

- MILS Multiple Independent Levels of Security/Safety
- MSLS Multiple Single Level Security/Safety
- MLS Multi-Level Secure/Safe
- PCS Partition Communication System
- CORBA Common Object Request Broker Architecture
- NEAT Non-bypassable, Evaluatable, Always-invoked, Tamper-proof
- NIU Network Interface Unit
- ORB Object Request Broker
- O/S Operating System
- CC Common Criteria
- EAL Evaluation Assurance Level
- ARINC 653 Safety Community Standard for Time and Space Partitioning
- DMA Direct Management Access
- MMU Memory Management Unit
MILS Hardware Based Partitioning Kernel
   AAMP7                     Rockwell Collins

MILS Software Based Partitioning Kernel
   Integrity-178   Green Hills Software
   LynxOS-178      LynuxWorks
   VxWorks AE Secure        Wind River

MILS Middleware
   PCS and ORBexpress   Objective Interface Systems, Inc.
   MILS TestBed         University of Idaho
   MILS TestBed         Naval Post Graduate School