MAC Framework Port to OpenDarwin Brown Bag Lunch

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McAfee Research

MAC Framework port to Open Darwin Brown Bag Lunch

- TrustedBSD MAC Framework
  - Extensible kernel access control framework
  - Permits new kernel security policies to be loaded via loadable kernel modules
  - Supports a variety of security policies
  - DARPA-sponsored R&D on FreeBSD platform
- Follow-on work
  - Port NSA's FLASK/TE from SELinux to FreeBSD as a MAC Framework policy module
  - Port MAC Framework and “SEBSD” module to Darwin

Talk Outline

- Background on CHATS, CBOSS
- Abbreviated design and implementation of TrustedBSD MAC Framework
- Introduction to SEBSD policy module
- Port of MAC Framework to Darwin, Mac OS X
- Implications for SEBSD policy module
- New capabilities
- Areas for future work

CBOSS: Community-Based Open Source Security

- DARPA CHATS program under Doug Maughan
  - Create a partnership between leading open source developers and industry security R&D laboratory
  - Additional research and development funding for maturity of MAC Framework, development of SEBSD, port of both to Darwin/Mac OS X
- By improving the security of open source systems, DARPA can impact a wide variety of COTS and research products
  - Rapid technology transfer path of open source

CBOSS Project Overview

- Many extremes in OS security work:
  - Write OS from the ground up
  - Don't change the OS at all
  - Maintain a local version with extensive modifications
- Avoid pitfalls of these approaches by:
  - Leveraging ability to modify open source FreeBSD operating system to provide security extensibility services
  - Working with open source developers to assure knowledge, process, technology transfer

Benefits to the CBOSS Approach

- Support for secure out-of-the-box COTS operating systems
  - Rapid time-to-market of open source already showing concrete benefits
  - Berkeley-licensed open source software rapidly transfers to closed source software products
  - Better support for future security research through extensibility and stronger support infrastructure
  - Long-term improvements in architecture, implementation, process outside of the research community

TrustedBSD MAC Framework

TrustedBSD MAC Framework

- Problem with security extensions for OS's:
  - Expensive to develop, deploy, and maintain
  - Extensions often conflict
  - There is no “one right policy” for all consumers
- Solution:
  - Improve operating system structure to better support security extensions
  - Provide common elements of policies to reduce redundant work by policy implementors
  - Avoid committing to any one specific policy

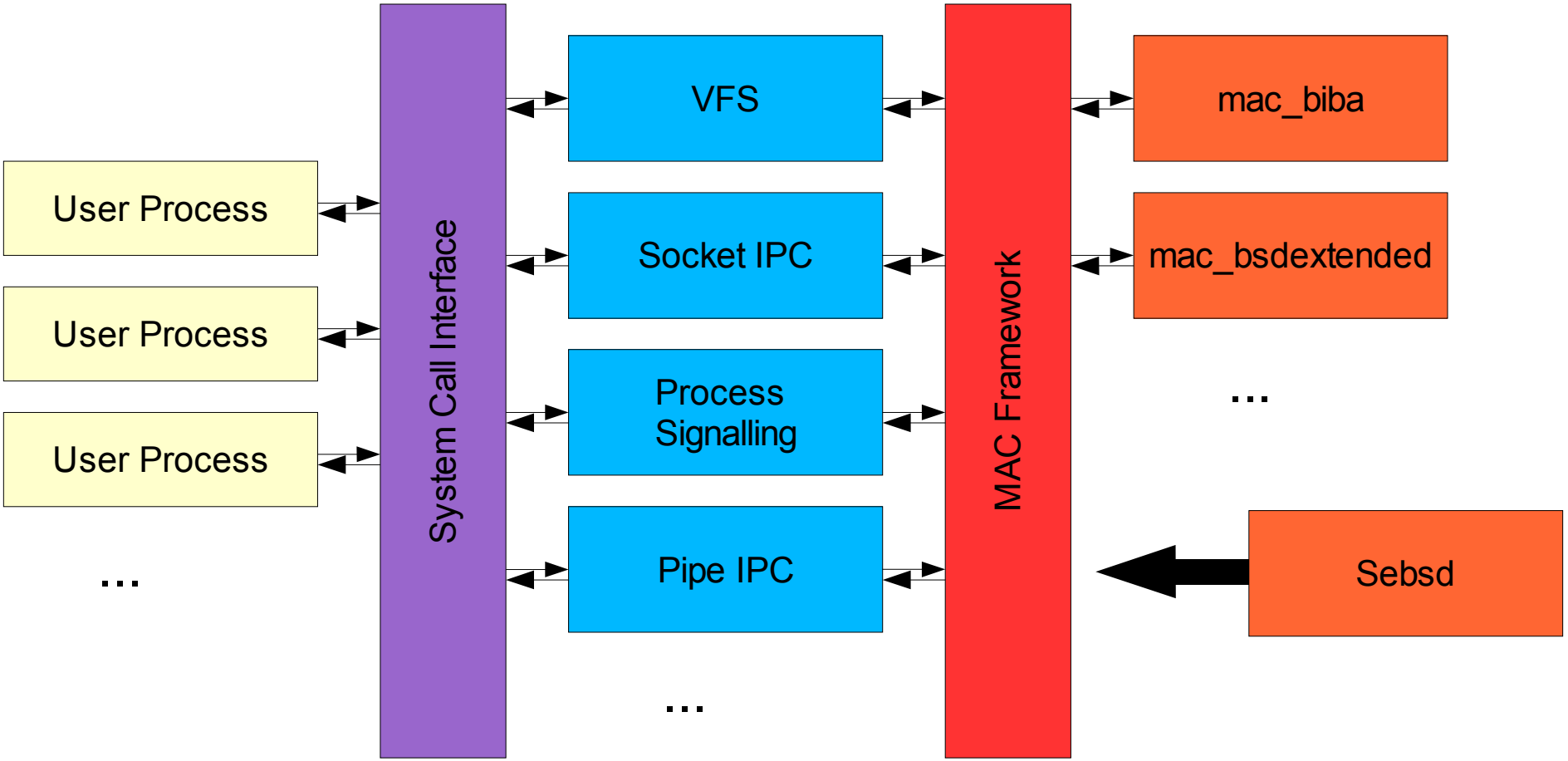
Why a Framework?

- Support required in the operating system for new security services
  - Costs of locally maintaining security extensions are high
  - Framework offers extensibility so that policies may be enhanced without changing the base operating system
- There does not appear to be one perfect security model or policy
  - Sites may have different security/performance trade-offs
  - Sites may have special local requirements
  - Third party and research products

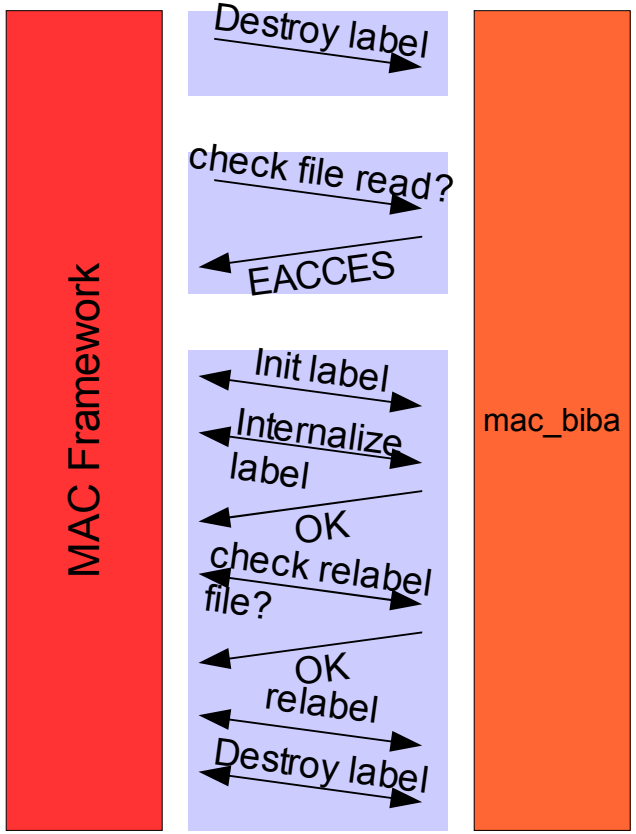
Kernel MAC Framework Elements

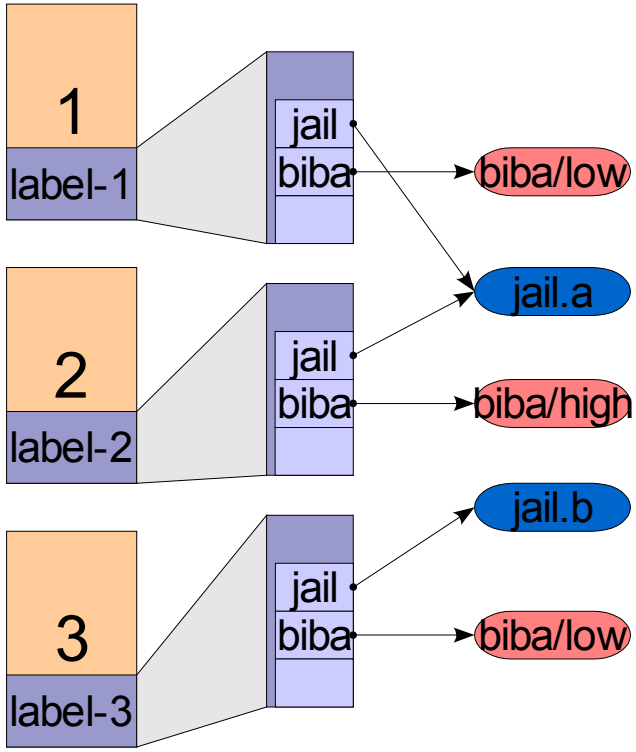
- Policies are encapsulated in kernel modules
- Framework captures common policy elements:
  - Labeling service allows policies to label system objects
  - Policies may perform access control checks to limit access to system objects and services
- When multiple policies are present, their results are (usefully) composed
- Policy-aware and security-aware applications may access and maintain labels on system objects

Kernel MAC Framework



Policy Entry Point Invocation
Policy-Agnostic Labeling Abstraction





Modifications to FreeBSD to Introduce MAC Framework

- A variety of architectural cleanups
  - Audit and minimize use of privilege
  - Centralize inter-process access control
  - Centralize discretionary access control for files
  - Clean up System V IPC permission functions
  - Prefer controlled and explicit export interfaces to kmem
  - Combine *cred structures into ucred; adopt td_ucred
  - Correct many semantic errors relating to credentials
  - Support moves to kernel threading, fine-grained locking, SMP

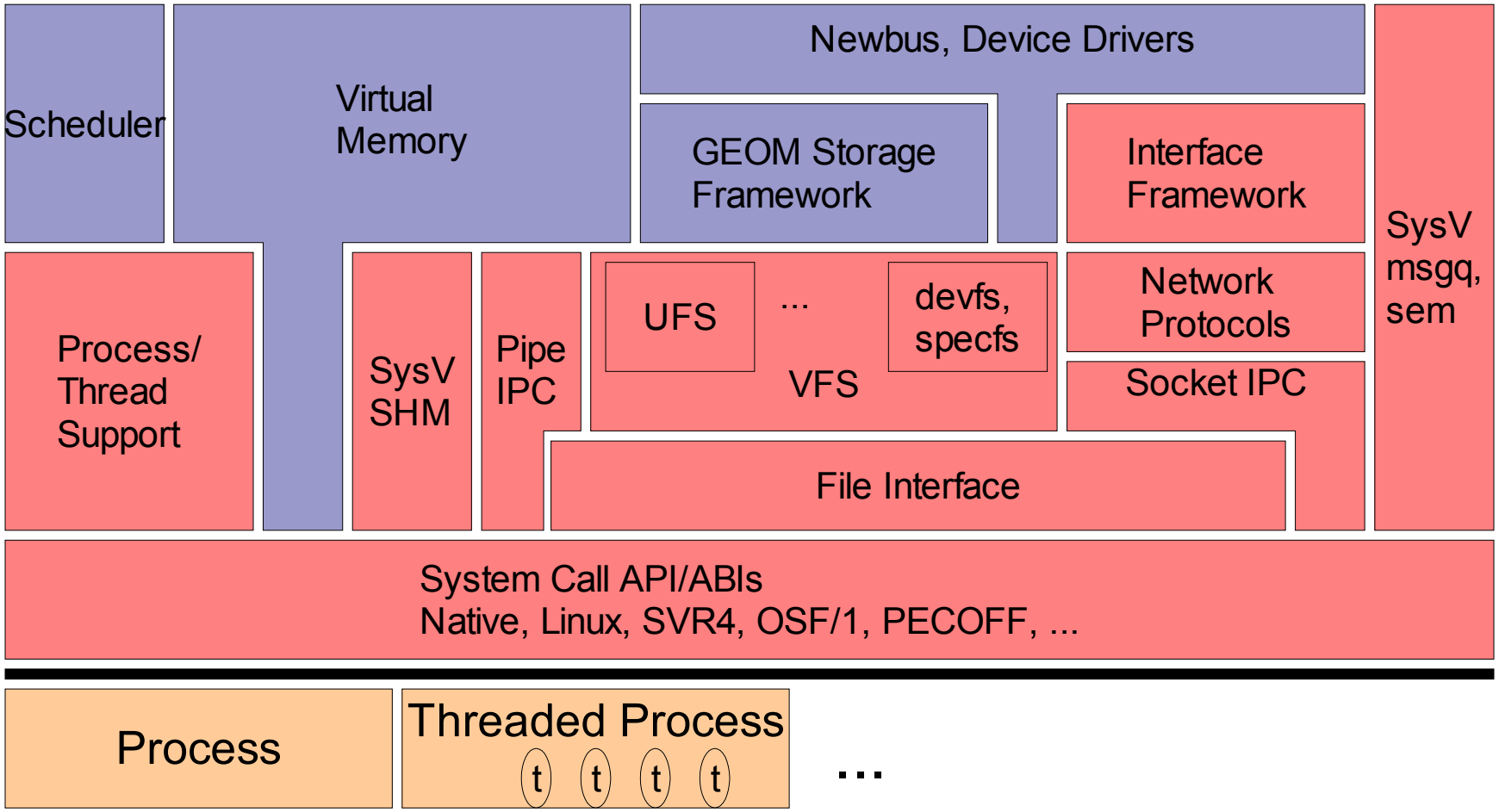
Modifications to FreeBSD to add the MAC Framework (cont)

- Infrastructure components
  - Add support for extended attributes in UFS1; build UFS2
- Actual MAC Framework changes
  - Instrument kernel objects for labeling, access control
  - Instrument kernel objects for misc. life cycle events
  - Create MAC Framework components (policy registration, composition, label infrastructure, system calls, ...)
  - Create sample policy modules
  - Provide userspace tools to exercise new system calls
  - Modify login mechanisms, user databases, etc.

List of Labeled Objects

- Processes
  - Process credential, process
- File System
  - Mountpoint, vnode, devfs directory entries
- IPC
  - Pipe IPC, System V IPC (SHM, Sem, Msg) , Posix IPC
- Networking
  - Interface, mbuf, socket, Inet PCB, IP fragment queue, Ipsec, security association

Integration of MAC Framework into FreeBSD



Sample Policy Modules

- mac_test regression test, stub, null modules
- Traditional labeled MAC policies
  - Biba fixed-label integrity, LOMAC floating-label integrity
  - Hierarchal and compartmented Multi-Level Security (MLS)
  - SELinux FLASK/TE “SEBSD”
- Hardening policies
  - File system “firewall”
  - Interface silencing
  - Port ACLs
  - User partitions

Port of the TrustedBSD MAC Framework to Open Darwin

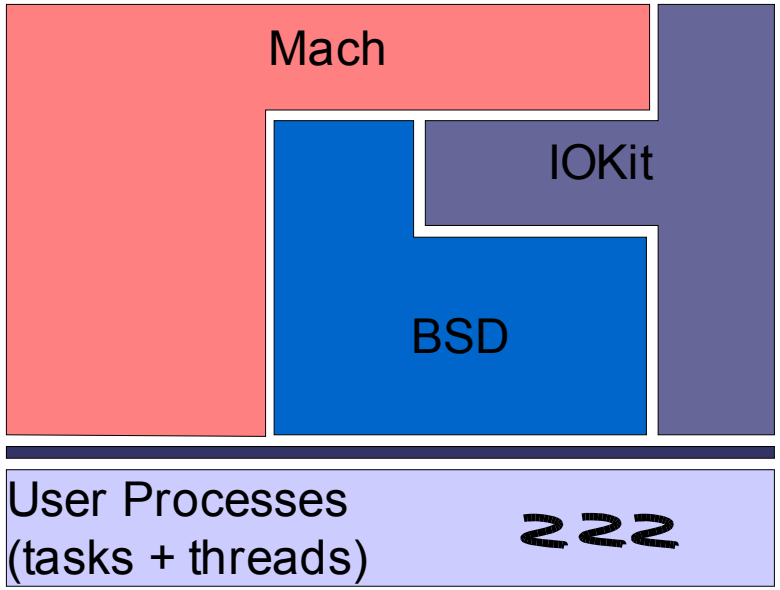
Port of the TrustedBSD MAC Framework to Open Darwin

- Adapt MAC Framework to Darwin
  - Strong research and development motivations
  - Structural and implementation similarities to FreeBSD
- Targeted at Open Darwin 6.6 (Jaguar 10.2.8)
  - Working only from open source components
  - Also “extended” some binary-only components
- Currently R&D Prototype
  - Illustrates concept/approach, but not yet production-quality
  - mac_test, SEBSD policy modules only currently

Strategy: Migrate MAC Framework to Darwin, Port SEBSD as SEDarwin

- Exploit common source code and design roots of FreeBSD and Darwin
  - Port dependencies, such as extended attributes
  - Migrate MAC Framework to Darwin
  - Expand MAC Framework and policies to address Darwin-specific features, such as Mach IPC
    - Requires MAC Framework to sit between various layers
  - Modify Darwin userspace applications
  - Produce adapted MLS, SEBSD TE policies

Architecture of Darwin Kernel (Gross Over-Simplification)



- Mach provides low-level IPC, memory, synchronization primitives
- IOKit provides OO driver infrastructure
- BSD provides high level IPC, networking, storage services

Infrastructure: File System Extended Attributes

- Many policies rely on additional policy-specific security attributes
  - Provide a generic extended attribute meta-data service
  - UFS1 on FreeBSD: extended attributes in per-fs/attribute backing files indexed by inode number
  - UFS2 on FreeBSD: additional file block/extent for per-inode metadata
- Ported UFS1 extended attributes to VFS, HFS+
  - Slower and less tightly integrated, but easier to port
  - No generation number in HFS+ to detect inconsistencies

Additional Infrastructure

- Port “sbuf” abstraction to Darwin kernel
  - Safe string manipulation for labels
- Port strsep() and other string management
- Port FreeBSD SMPng condition variables
  - Wrap Mach wait_queue_t with higher level synchronization “struct cv” primitive
- Modify BootX to preload non-binary data
  - Pre-load policy file during boot before file systems are mounted

Adapt MAC Framework to Mach Synchronization and Allocation

- Because we interact directly with Mach, must make use of Mach-level primitives
- All MAC Framework components assumed to run free of funnel
  - Except where kernel structures are covered by funnel
- Synchronization
  - FreeBSD and Mach mutexes basically the same
  - Condition variable changes
- Memory allocation
  - Move to Mach kmem allocator, zone allocator

BSD and Mach Layers

- TrustedBSD MAC Framework on FreeBSD addresses only BSD-layer primitives
  - BSD processes
  - BSD VFS
  - BSD networking
  - BSD IPC
- Initial port addressed only BSD components
  - Maintain labels and access control only on BSD objects
  - Now addressing Mach components

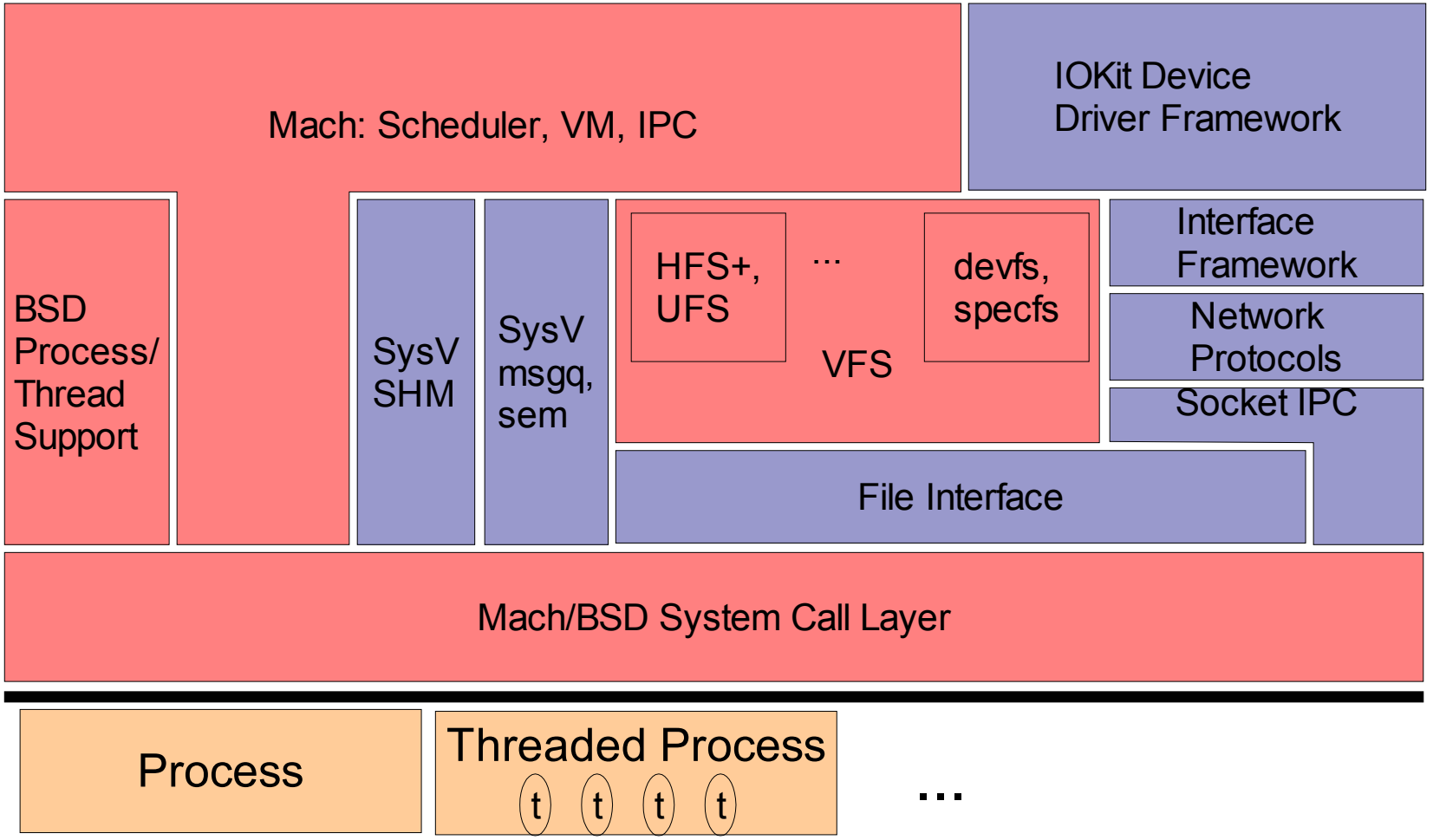
Mach Integration

- Add additional initialization stages
- Added label and label lock to Mach Task
  - Maintain BSD process label as “primary” label for tasks bound to processes
  - Maintain BSD process label as “primary” label for tasks bound to processes
  - Need a leaf lock to avoid violating lock orders
- Add label to Mach port
  - Export label information using message trailers
  - Still exploring how to do this best/fastest/simplest/...

mach_init and bootstrap namespace

- Mach_init name space critical to security
  - Ability to spoof services throughout desktop/system
  - Especially with untrusted root
- Export label management, access decision functions to userspace
  - Allow user processes to maintain labels on objects
  - May request access control decisions using passed labels, message trailer
- Exploring “object handle” object attached to Mach port

Integration of MAC Framework into Darwin Prototype



System Calls, Support Libraries

- Extended attribute system calls, support library
- Userland tools for extended attributes
- MAC label system calls, support library
- Userland tools for manipulating MAC labels
- Modifications to libkvm, ps, ls, ifconfig

Modifications to Login Window

- Closed source component in Mac OS X
- Provided modified exec(), setlogin() library calls for loginwindow
  - Track logins and required label changes
  - Intercept execution step to perform necessary relabel operations
- Lack of inheritance from login session creator presents substantial obstacle
  - Not just for MAC, also for resource limits, audit, etc.

Issues and Concerns

- Lack of unified build infrastructure for Darwin
  - Challenging to build and maintain extensive modifications
- Serious binary compatibility issues
  - Drivers when expanding data structures for labels
  - Had to back off initial port of network stack components
- Mach wait_queue primitive much weaker
- Mach IPC
  - Mach IPC primitives very weak, semantically
  - Requires applications to be much more involved in access control than in traditional UNIX system

Additional Issues and Concerns

- HFS+ lacks generation numbers
  - May break NFS, also prevents us from checking consistency of attributes with file system objects
  - Prefer that HFS+ had a native extended meta-data service
- Source code for loginwindow not available
  - Jaguar substantially less mature than Panther
  - While there have been improvements to the login process and credential management, still much to be done
- Jaguar applications behave poorly on failure

Additional HFS+ concerns

- TrustedBSD MAC Framework splits ownership of label management with file system
  - Performs access control checks at cross-file system layer
  - Some file systems provide per-label storage
  - Other file systems rely on VFS layer labeling
- Darwin offers a number of stronger file system system calls
  - Permits more direct reading, manipulating of disk catalog
  - Requires MAC Framework to become more involved in HFS+, not to mention layring issues

Things That Went Quite Well

- MAC Framework ported quite well for basic BSD objects
  - Little or no problem porting for processes, vnodes
  - Some improvement in Darwin abstractions required
  - Tools and libraries “just worked”
- SEBSD slid over without a hitch
  - Once MAC Framework pieces were there, it “just worked”
- Many applications do behave well, especially if they don't treat HFS+ as “special”

Capabilities: High Level Overview

- Insufficient time to discuss policies in detail
- Policies may implement a variety of models
  - Policies attach to the system during boot or at run-time
  - May implement controls on interesting subsets of system
  - May instrument access control decisions associated with a variety of system services in kernel and user space
  - May maintain additional security labels on system objects
- Information flow policies largely focus of .mil
- Hardening, discretionary policies also possible

Where We're Going Next

- Four dimensions into which we are expanding the work:
  - Expand coverage of BSD objects – IPC, etc
  - Expand into the Mach space: a “must do” to provide comprehensive enforcement, but will raise synchronization and performance issues
  - Expand SEBSD policy from minimalist demo policy to useful enforcement policies
  - Port MLS policy module
  - Explore impact of this work on OS X more extensively

Conclusion

- MAC Framework provides access control extensibility on FreeBSD
- Proof-of-concept port of MAC Framework to Darwin at early prototype phase
  - Labeling of some but not all objects
  - Enforcement of some but not all access methods
  - Limited file system support, application integration
- Successfully running with ported SEBSD policy module, others underway

How to Get the Code

- http://opensource.nailabs.com/
- http://www.TrustedBSD.org/
- Strict version requirements currently:
  - Jaguar 10.2.8 + Development Kit
- Source via CVSUP
  - Follow bootstrap_instructions.txt very carefully
  - Mach components very much in flux