CAPP-Compliant Security Event Audit System for Mac OS X and FreeBSD

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Introduction

- Background
- Common Criteria, CAPP, evaluation
- What is security event audit?
- Audit design and implementation considerations
- Differences between UNIX and Mac OS X
- FreeBSD port
- OpenBSM

Organizations

- Apple Computer, Inc.
  - Tight hardware/software integration, single vendo
- McAfee Research, McAfee, Inc.,
  - Computer security research and engineering
    - Primarily DoD customers, but some commercial
- SAIC
  - Many things, but among them, evaluation lab
- TrustedBSD Project
  - Trusted operating system extensions for FreeBSD

Trusted Operating Systems

- Notions originated in security research and development during 1950's – 1970's
  - Trustworthy and security systems for US military
  - Later, scope expands
- Two focuses
  - Specific security feature sets
  - Assurance
- 1980's–1990's “Orange book”
- 1990's–2000's NIAP and Common Criteria (CC)

Role of Evaluations

- Security evaluations controversial
  - Does the evaluation address real security needs?
  - Is the goal more paper or a better product?
  - Do we know more after an evaluation?
- Security evaluations are, however, a reality
  - Cannot sell to US DoD (and others) without evaluation
  - Inclusion of many necessary security features has been driven by evaluation requirements

Common Criteria

- ISO standard and model for security evaluation
  - CC defines vocabulary and processes
  - Protection Profiles define functional requirements
  - Evaluation Assurance Level (EAL) defines assurance target
- Two widely used protection profiles for operating systems
  - CAPP, LSPP
  - Other protection profiles for other sorts of products

NCSC Orange Book-Derived Protection Profiles

Common Access Protection Profile (CAPP)	Derived from Orange Book C2 Multiple authenticated users Separation of administrative role Discretionary access control Security event auditing Minimal coverage of network concepts
Labelled Security Protection Profile (LSPP)	Derived from Orange Book B1 CAPP + Mandatory Access Control (MAC) Role-Based Access Control (RBAC) Multi-Level Security (MLS) Enhanced security event auditing Typically shipped with labelled networking

Assurance

- Assurance arguments critical to evaluation
  - Documentation of goals
  - Documentation of assumptions
  - Documentation of system design
  - Argument system implementation matches design
  - Documentation of process
- Assurance is measured in paper
  - For lower EAL, measurements < 1 ~~yard~~metre
  - For higher EAL, measurements > 1 ~~yard~~metre

Common Criteria Evaluation

- Five easy steps
  1. Select a protection profile, assurance level
  2. Write a security target, evaluation evidence
  3. Add features implementing missed requirements
  4. Write a very large cheque
  5. Work with evaluation lab through testing cycle
- Shortcuts
  - Evaluate to a cut down protection profile (PR)
  - Contract evaluation lab to write your evidence

UNIX and CAPP

- Most commercial UNIX systems meet CAPP requirements with minor configuration tweaks
- Three common extensions required:
  - Enhanced discretionary access control – ACLs
  - Security event audit
  - Authentication and password policy enforcement
- Of these, audit is the most difficult (expensive) to add to a UNIX system

What is Security Event Audit?

- Log of security-relevant events
  - Secure
  - Reliable
  - Fine-grained
  - Configurable
- A variety of uses including
  - Post-mortem analysis
  - Intrusion detection
  - Live system monitoring, debugging

Common Criteria and Audit

- CAPP defines functional requirements
  - Audit will provide comprehensive logging of security events defined in CAPP and security target
  - Reliability and robustness requirements key
- LSPP extends audit to include MAC labelling and decision information

CAPP Requirements (excerpt)

CAPP Requirements Table

CAPP Category		Requirement	Description
5.1.1.1	FAU_GEN.1	Audit Data Generation	The TSF shall be able to generate an audit record of the auditable events listed in column “Event” of Table 1 (Auditable Events). This includes all auditable events for the basic level of audit, except FIA_UID.1's user identity during failures.
5.1.1.2	FAU_GEN.1	Audit Data Generation	The TSF shall record within each audit record at least the following information: (a) Data and time of the event, type of the event, subject identity, and the outcome (success or failure) of the event; (b) additional information specified in Table 1.
5.1.2.1	FAU_GEN.2	User Identity Association	The TSF shall be able to associate each auditable event with the identity of the user that caused the event.
5.1.3.1	FAU_SAR.1	Audit Review	The TSF shall provide authorized administrators with the capabiity to read all audit information from the audit records.
5.1.3.2	FAU_SAR.1	Audit Review	The TSF shall provide the audit records in a manner suitable for the user to interpret the information.
5.1.4.1	FAU_SAR.2	Restricted Audit Review	The TSF shall prohibit all users read access to the audit records, excet those users that have been granted explicit read-access.

Audit Basics

- Audit records describe individual events
  - Attributable (to an authenticated user)
  - Non-attributable (no authenticated user)
  - Selected (configured to be audited)
- Most audit events fall into three classes
  - Access control
  - Authentication
  - Security management
- Audit log files are called “trails”

Audit Log Security

- Audit must be non-bypassable
- Right to add records to trail must be controlled
- Setting and viewing the audit configuration must be controlled
- Audit review must be controlled, assignable
- UNIX syslog has none of these properties!

Audit Reliability

- Reliability is key to audit implementation
  - If an event is auditable, selected, and occurs, then **it must be audited**
  - If an event is auditable, selected, but cannot be audited, it **must not occur**
- Ability to fail-stop system for predictable loss
- Upper bound on loss in the event of unexpected failure (i.e., power loss)
- UNIX syslog can't do this either

Mapping CAPP Audit into UNIX

- CAPP does not impose a specific OS structure
  - Does require a Trusted Code Base (TCB)
- UNIX structure is layered
  - Operating system kernel (TCB)
  - Operating system user space (TCB)
  - Other operating system user space (user)
- All audit events sourced in TCB
  - Authentication events mostly user space
  - Access control events mostly kernel space

Auditable Events in UNIX

- Access control
  - System calls checking for super user privilege
  - System calls with file system access control checks
    - Including path name lookup!
  - Login access control decisions
- Authentication, Account Management
  - Password changes, successful authentication, failed authentication, user administration
- Audit related events

Mapping CAPP Audit into UNIX

- Typical design choices
  - Audit event stream managed by kernel
  - Most records generated by system calls
  - Other records submitted by system applications using system call; privilege required
  - UNIX DAC permissions protect audit log
  - Helper daemon manages audit configuration, possibly writes audit stream
  - Process state extended with pre-selection masks and audit user ID

Audit and FreeBSD

- FreeBSD is in every sense, a classic UNIX
- All UNIX design choices on previous slide apply
  - Will tell you more in a few minutes

Audit and Mac OS X

- Mac OS X is based on a UNIX kernel
  - Most UNIX audit design choices apply
  - Kernel also offers Mach IPC
- Mac OS X user space relies on extensive IPC
  - UNIX processes cross boundaries with setuid
  - Mac OS X uses IPC to privileged daemons
- Extend Mach message trailers with audit fields
  - Allows privileged daemons to attribute audit events to current subject

Audit and Mac OS X (cont)

- Mac OS X process tree not traditional UNIX
  - UNIX process tree descends from single parent
  - In Mac OS X, user applications launched by a single privileged process (window server)
- Modification to approach that assumes all audit properties can be set at login and then inherited
  - Application launch services had to learn about audit

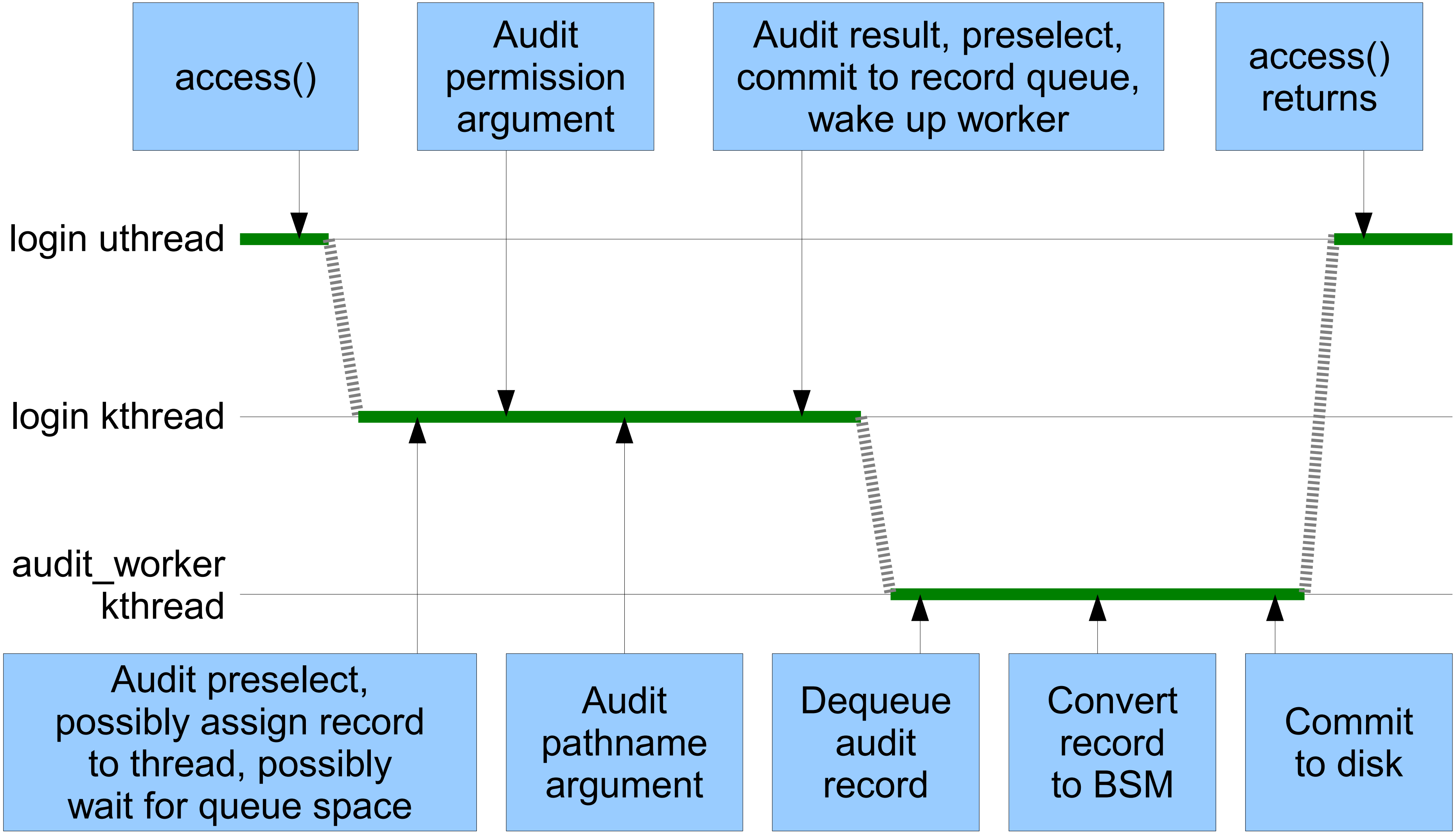
Modifications to FreeBSD, Mac OS X Kernels

- System call entry pre-selects, allocates record
- System call arguments, return values
- System call exit commits record
- Audit record queue implementation
- Audit event trigger mechanism
- Conversion from internal record to BSM
- Audit system calls
- Mach message trailer audit fields (Mac OS X)

Modifications to FreeBSD, Mac OS X User Space

- Audit library
- Audit trail viewer, reduction tool
- /etc/security audit configuration / databases
- Audit daemon to manage trails, triggers
- Set audit context at user login
- Application launch support for audit (Mac OS X)
- Audit in management tools, daemons

Sample Audit Control Flow



access()

Audit permission argument

Audit result, preselect, commit to record queue, wake up worker

access() returns

Audit preselect, possibly assign record to thread, possibly wait for queue space

Audit pathname argument

Dequeue audit record

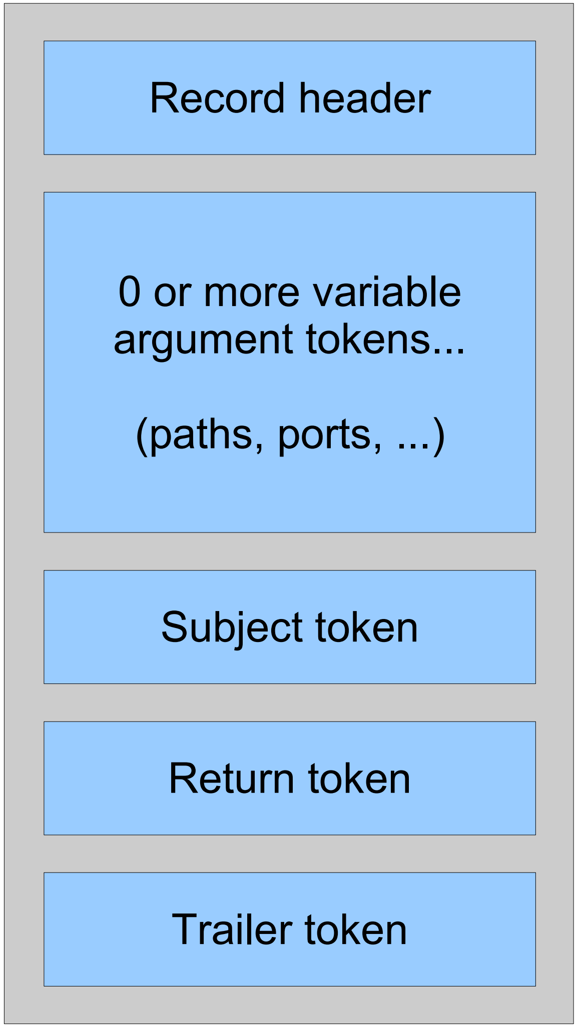
Convert record to BSM

Commit to disk

BSM APIs and File Formats

- Sun's Basic Security Module (BSM) de facto industry standard
  - File formats
    - Token-oriented audit trail format (almost TLV)
    - Audit configuration and databases
  - APIs
    - Construct, parse, process audit record streams
    - Manage audit state, pre-selection model
- Compatibility with many existing libraries and tools for free

BSM Audit Record Format



Record header

0 or more variable argument tokens...

(paths, ports, ...)

Subject token

Return token

Trailer token

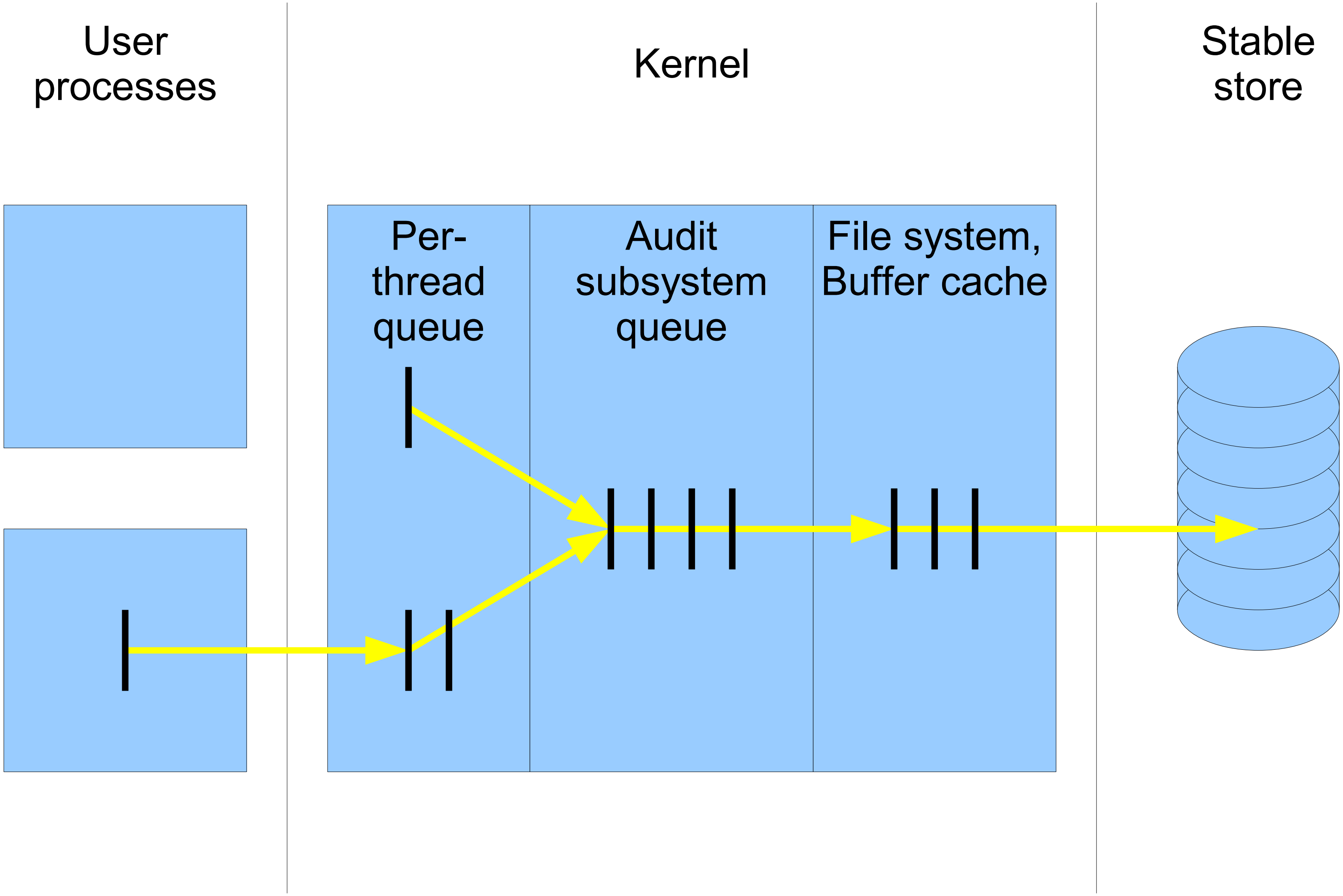
```
header,129,1,AUE_OPEN_R,0,Tue Feb 21 00:12:23 2006,
+ 253 msec
argument,2,0,flags
path,/lib/libc.so.6
attribute,444,root,wheel,16842497,11663267,46706288
subject,-1,root,wheel,root,wheel,319,0,0,0.0.0.0
return,success,6
trailer,129

header,108,1,AUE_CLOSE,0,Tue Feb 21 00:12:23 2006, +
255 msec
argument,2,0x6,fd
attribute,444,root,wheel,16842497,11663267,46706288
subject,-1,root,wheel,root,wheel,319,0,0,0.0.0.0
return,success,0
trailer,108
```

Thinking About Audit Reliability

- Correspondence between auditable events and audit records tricky
  - Audit record production is a queue split over several system components
  - Must bound end-to-end queue size based on available storage resources
  - Must bound end-to-end queue size based on maximum permissible loss
- "Fail-stop" must commit remaining records gracefully before stopping

Audit Queuing



User processes

Kernel

Stable store

Audit Selection

- Potential for audit record volume huge
  - Terabytes/hour on busy, fully audited system
- Two key points for audit record selection
  - Audit pre-selection to limit audit records created
  - Audit post-selection, or reduction, to eliminate undesired records after creation
- Mac OS X and FreeBSD support both models
  - Administrator can apply filters to users at login time
  - Administrator can use tools to reduce trails later

Audit Configuration: Pre-Selection

- Over 350 event types
  - Most of them meaningless individually
- Each event assigned to one or more classes
- Class masks assigned to users

```
0:AUE_NULL:indir system call:no
1:AUE_EXIT:exit(2):pc
2:AUE_FORK:fork(2):pc
3:AUE_OPEN:open(2) - attr only:fa
4:AUE_CREAT:creat(2):fc
5:AUE_LINK:link(2):fc
6:AUE_UNLINK:unlink(2):fd
7:AUE_EXEC:exec(2):pc,ex
8:AUE_CHDIR:chdir(2):pc
...
```

```
0x00000000:no:invalid class
0x00000001:fr:file read
0x00000002:fw:file write
0x00000004:fa:file attribute access
0x00000008:fm:file attribute modify
0x00000010:fc:file create
0x00000020:fd:file delete
0x00000040:cl:file close
0x00000080:pc:process
0x00000100:nt:network
...
```

```
root:lo:no
audit:lo:no
test:all:no
www:fr,nt,ip:no
...
```

FreeBSD Port

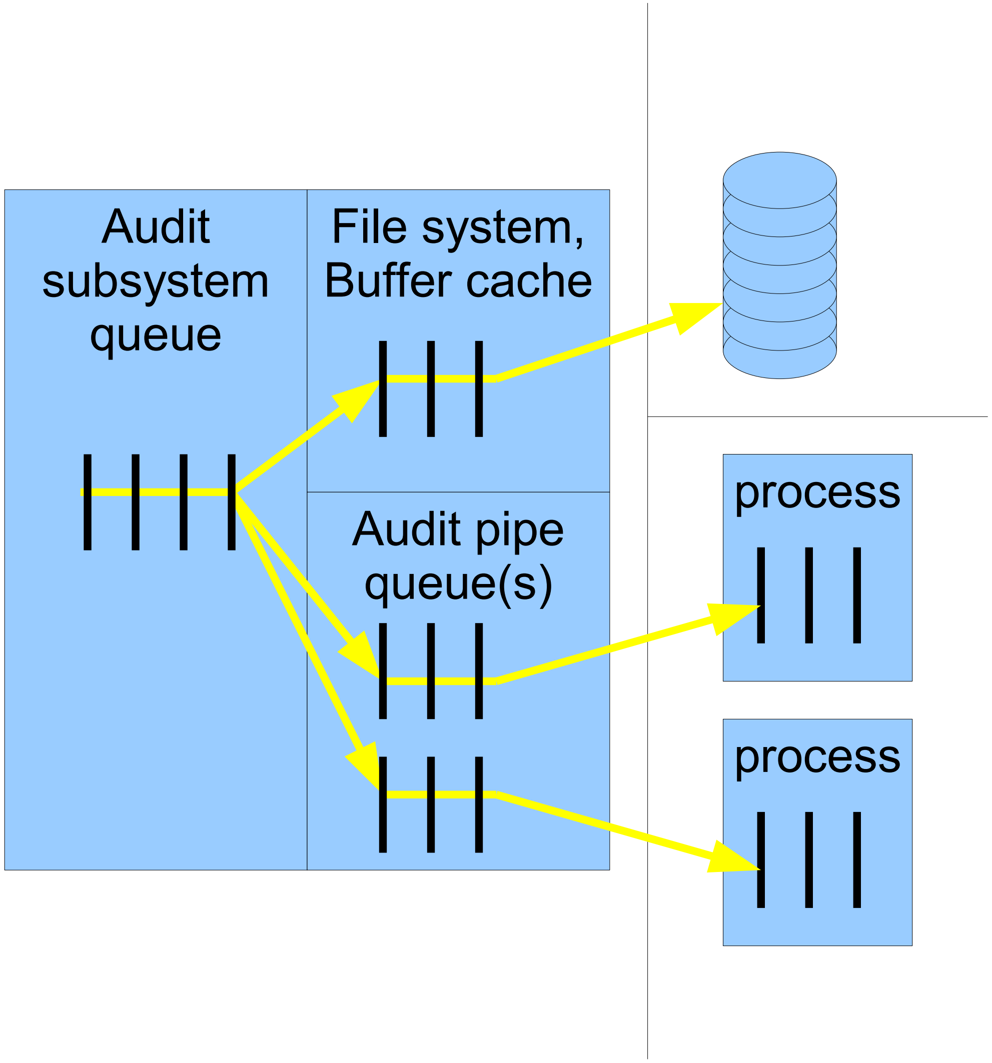
- FreeBSD Operating System
  - BSD-licensed 4.4BSDlite2 derivative OS
  - Widely used in high-end embedded, networking, ISP, server spaces.
  - One of the source code bases for Mac OS X
- More classic UNIX operating system
- Common code base makes it an easy target
- Currently present in FreeBSD 7.x development tree, will be merged as of 6.2 release

Changes Made Porting to FreeBSD

- Endian-independent implementation
  - Also now important on Mac OS X
- Discard Mac OS X mach trailer support
- Add 64-bit token support
  - Also now important on Mac OS X
- Significant clean-up, debugging, documentation
- Largely different user space integration
- Introduce audit pipes

Audit Pipes

- Historically, audit for post-mortem analysis
- Today, for intrusion detection / monitoring
- Audit pipes provide live record feed
  - Lossy queue
  - Discrete audit records
  - Independent streams



OpenBSM

- BSD-licensed BSM library, tools, docs
- Portable across many platforms
- Implements Sun BSM with some extensions
- Foundation for FreeBSD, future Mac OS X use
- http://www.OpenBSM.org/

Conclusion

- Security event auditing is critical to successful security evaluation
  - Some argue audit is a critical security feature
- Complex reliability requirements
- Complex security requirements
- Open source common to FreeBSD, Mac OS X
  - http://www.TrustedBSD.org/, http://www.OpenBSM.org/
- API/file format compatibility with Solaris