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Rehabilitating NFS Security

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In 1984, NFS deserved its security reputation

- AUTH_SYS isn't real authentication
  - AUTH_SYS uses publicly available information (uids) to authenticate
  - Beside, it supported only 16 groups

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NFS deserved its security reputation (continued)

- In lieu of authentication, NFS offered access control based on source client IP address
  - Access control usually enforced only at mount time partly because MOUNT and NFS are separate services listening on different ports
  - Attackers could eavesdrop for file handles, bypass MOUNT protocol, and so circumvent intended controls

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NFS deserved its security reputation (continued)

- Initial transport was UDP
  - Thus simple-password-based authentication impractical
  - Drive-by-shootings easier with UDP: spoof a source UDP address, fake an identify, and use WRITE to corrupt a file
  - Security hardening technologies impossible/hard to use:
    - TCP-Wrappers
    - firewalls
    - SSH

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NFS deserved its security reputation (continued)

- Protocol specifications for adjunct services (lock manager, status monitor, rquota) weren't specified to use the same access controls, transport type, authentication mechanism, etc. as the NFS/MOUNT session

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NFS deserved its security reputation (continued)

- Many early implementation errors.
  - The set of errors was captured in the SATAN tool of the early 1990s,
    - As a result this set is a non-issue among the major reference implementations and derivatives

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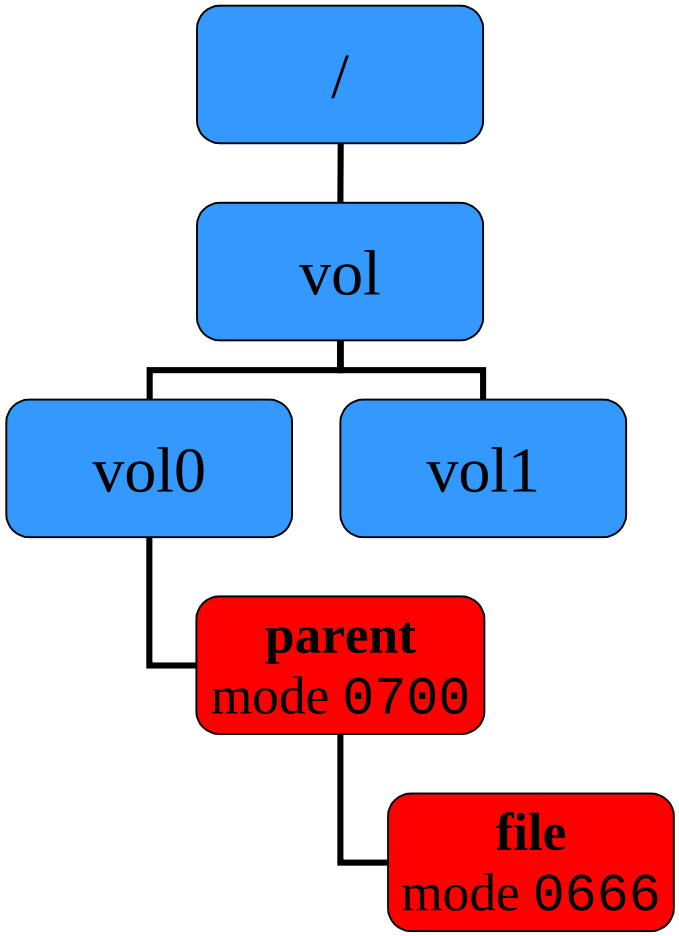
NFS deserved its security reputation (continued)

- Stateless model meant no wire OPEN operation, which led to need for persistent file handles
  - Persistent file handles permit attacks to circumvents permission ancestor directories
  - leaf **`file`** is writeable by all, even though **`parent`** directory is accessible by just the owner



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NFS deserved its security reputation (continued)

- 32 bit user and group identifiers forced enterprises to use a flat, common id namespace
  - fiefdoms within the enterprise that didn't go along couldn't share data across domains

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NFS deserved its security reputation (continued)

- Cached data on the client represented a security hole
  - e.g. One thing NFS got right was to (by default) map super-user (**root**) to an unprivileged user (**nobody**) on the server
    - But if the data for some other user was cached, **root** on the client could read it

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Why was NFS security created this way?

- Ease (use, deployment, implementation), cost, and performance trumped security considerations
  - NFS had to run in the kernel to perform
  - By the mid 1980s, UNIX kernels were widely divergent, creating challenges for porting the NFS reference code
  - hard stuff like security was done in user-space (MOUNT) or not at all

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Why was NFS security created this way?

- NFS was invented during the Camelot Era of the Internet (I.e. before Morris unleashed the Worm)
- Cold-War Era translated to very restrictive and bizarre Export Control regime

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Fixing security after the fact was hard

- 1987: AUTH_DH (AUTH_DES) was first crypto-based NFS/RPC security flavor
  - Few implementations
  - Yet ahead of its time; every NFS request and response authenticated
  - authenticated users, not NFS client nodes, to NFS servers
  - As a by product, solved too-many-groups problem of AUTH_SYS
- 1992: AUTH_KERB (Kerberos V4) shared same problems, fewer implementations
- Neither of above supported integrity or privacy
- Security experts soon scorned both for crypto weaknesses
  - A lot of development effort to produce something that was considered Dead-On-Arrival

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Fixing security after the fact was hard (continued)

- 1993: NFSv3 introduced the ACCESS operation which solved issue of access control to cached data. But:
  - It took 8 years before we could declare NFSv3 ubiquitous
  - The ACCESS operation is still poorly implemented in NFSv3 clients

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Fixing security after the fact was hard (continued)

- 1993: NFS/TCP implementations arrive
  - Unlike NFSv3, we still can't call it ubiquitous
  - Lots of problems in some implementations
  - Customers loathe to switch from UDP
    - We (the NFS implementers) have unwittingly addicted users to UDP

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Fixing security after the fact was hard (continued)

- POSIX (draft) ACL standards are implemented among major UNIX-based NFS clients, but
  - none of the NFS ACL protocols interoperate

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Fixing security after the fact was hard (continued)

- On non-Windows platforms, NFS had no real competition, hence less pressure to improve
  - While technically superior, more secure, AFS and DCE/DFS couldn't compete due to more expensive licensing terms
  - AFS and DCE/DFS didn't fail because they imposed security on the customer

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Despite improvement, the lowest common denominator was and remains:

- NFS version 2
- UDP
- AUTH_SYS
- no-per-NFS-request access control

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In hindsight, NFS ...

- should have been TCP only
- at mount time should have authenticated to server via per-host passwords (Kerberos would have followed)
- mounting should have been part of NFS protocol, thus binding mount authentication and authorization to subsequent NFS traffic
- In this alternate universe, NFS security would had a decent foundation that would allow incremental improvement
- In our universe, we've been forced to attack the major problems at once

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Progress in Fixing the NFS Security Image

- In the mid-1990s several events turned the tide in the dismal story of NFS authentication
  - IETF mandated new standards to have security
  - Sun ceded change control of ONC RPC and NFS to IETF
    - Now RPC and NFS had be secure if RFCs for them were to be published
  - IETF published Generic Security Services (GSS) and Kerberos V5 standards
  - Microsoft announced that NT 6.0 (W2k) would use Kerberos V5 as it primary authentication system
- This made it inevitable that the future of NFS authentication would be Kerberos V5

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Progress: Standardization, slow but effective

- 1997
  - IETF publishes RFC 2203: RPCSEC_GSS - RPC authentication using GSS
  - NFSv4 working group chartered with good security among goals
- 1997-1999 NFSv4 WG debates security model, resolving issue at Connectathon 1999
- 1998 U.S. government relaxes Export Controls
- 1999 First NFSv[23]/Kerberos V5 implementations ship (Hummingbird, Netmanage, Sun)
- 2000 RFC 3010, strawman NFSv4, mandates Kerberos V5
- 2002 First NFSv4/Kerberos V5 implementations ship (Network Appliance, early access Linux [U. of Michigan/CITI]).
  - NFSv[23] also supported.
- 2003 RFC 3530 published, obsoletes old NFSv4 RFC 3010
- Five implementations and counting. Better progress than previous strong authentication attempts.

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Progress: NFS Security Features Unique to version 4

- LIPKEY/SPKM – SSL-like security model
- NT-like ACL model with some UNIX concessions
- Volatile File Handles – potential to eliminate weaknesses of persistent file handles
- All functions (mounting, locking, filing, state recovery) bound to same fixed port, which is firewall friendly
- String-based user identifiers provide hook for authorizing users from foreign domains
- NFSv4 kicks the UDP habit

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Progress: NFSv4 - a marketing tool for NFS security

- Security, more than delegations, migration, and replication has driven interest in NFSv4
- Customers know it is an IETF standard, so it is secure
- Some of those customers are then surprised that NFSv[23] have Kerberos V5 too

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Preventing a relapse: What could go wrong

- UDP and NFSv4: Are implementers really going stay the TCP-only course?
- When will the other UNIX clients support Kerberos V5?
- Linux is the growth engine for NFS clients, making the need for a robust Linux (2.4) NFS/Kerberos V5 client urgent.
- NFSv4 ACLs don't perfectly map to POSIX ACLs. Unwillingness to accept imperfect mappings jeopardizes client ACL support
  - Perhaps we need a user-level NFSv4 ACL editor

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Preventing a relapse: What could go wrong (continued)

- Cross-domain authorization is in demand, but not implemented
  - NFSv4 WG is considering documents to aid implementers
- 56 bit DES for Kerberos V5 is insufficient
  - AES is the replacement, but Kerberos V5 standards for AES not done
  - Meanwhile, some NFS implementers are doing Triple DES
    - In software, Triple DES is very slow, very CPU intensive, will generate customer surprises

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Preventing a relapse: What could go wrong (continued)

- Hardware accelerated crypto is coming, but focus is likely on IPsec, not NFS
  - Hardware accelerated IPsec will outperform software AES (and software 3DES)
  - This raises specter of NFS security being considered solid, but too slow to be useful
  - NFSv4 WG is specifying a new mechanism for leveraging IPsec integrity and privacy while using Kerberos V5 for user to server authentication

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Questions?

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Backup Slides

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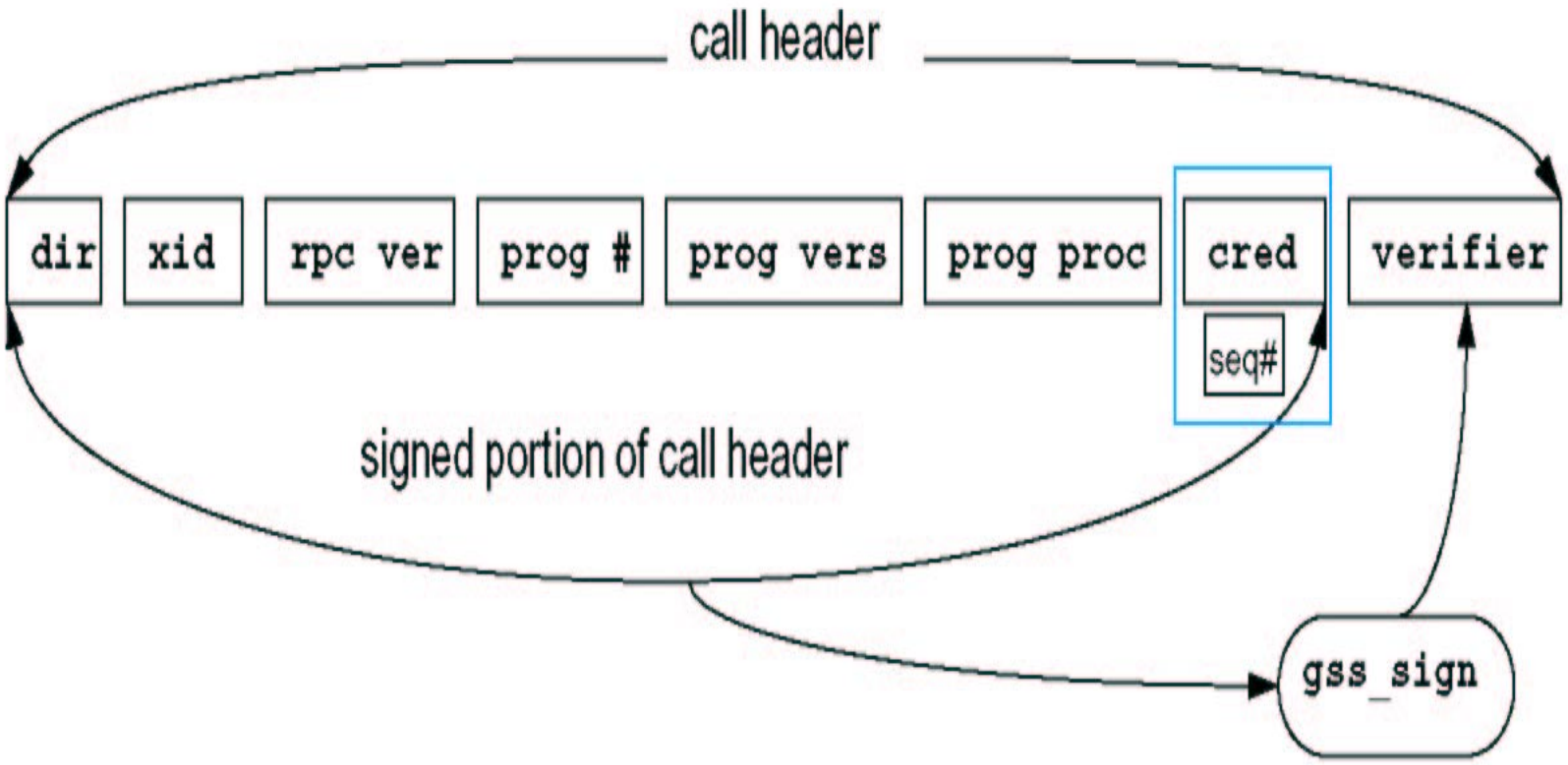
Overview of RPCSEC_GSS



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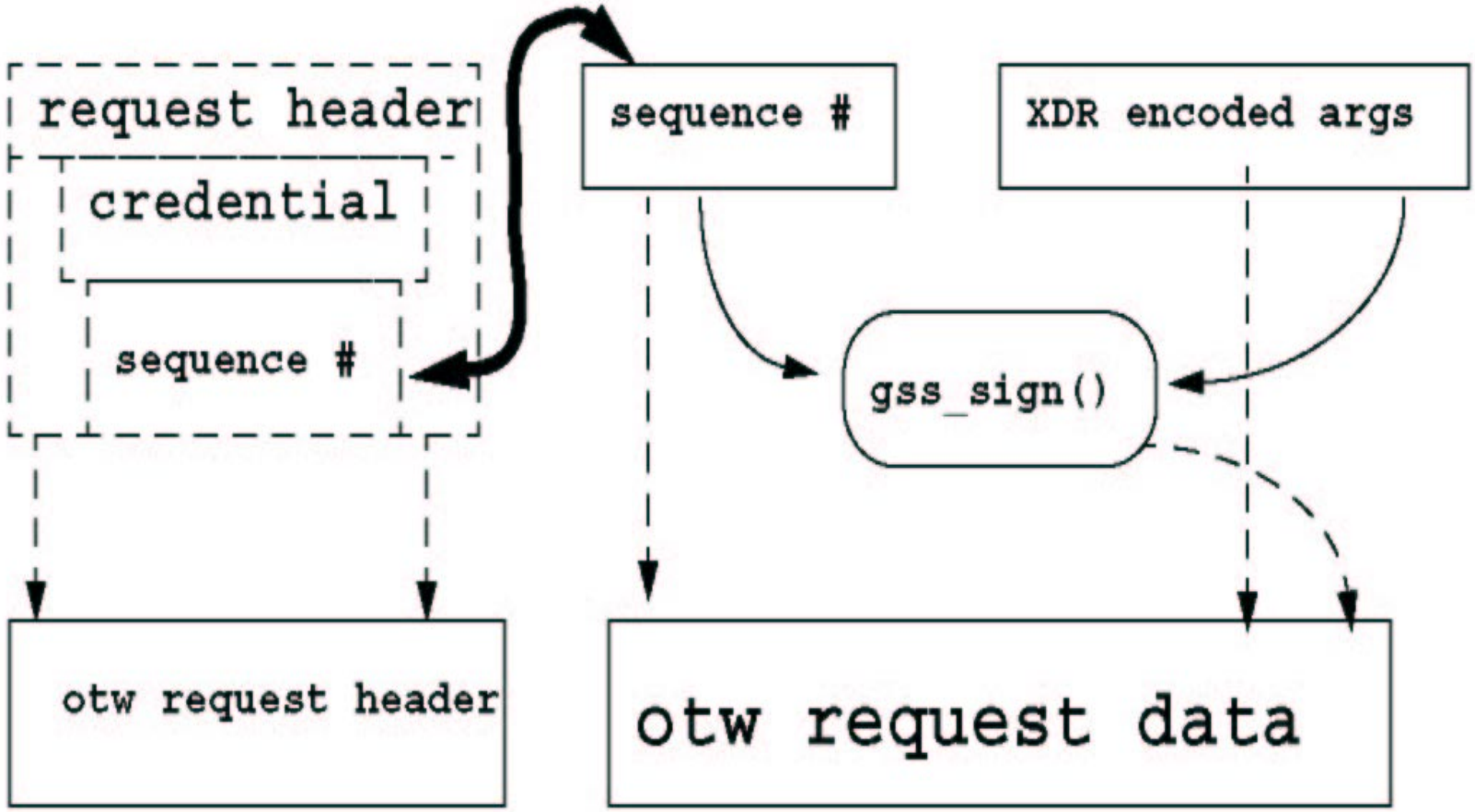
Overview of RPCSEC_GSS - Integrity



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Overview of RPCSEC_GSS - Privacy