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06-103: Key Encryption

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Problem and Design Goals

- SSC-3 will soon specify encryption key transfer in clear only
  - Keys can be entirely too valuable to an attacker
  - Transfer by reference isn't sufficient
- Goal: means of encrypting keys for transfer over a network
  - iSCSI and Fibre Channel (FCP) are primary concerns
  - IPsec (iSCSI) and FC-SP encrypt everything
    - Too high a price (e.g., hardware) to just protect keys
  - Just encrypting keys (wrapping) can be done in software
    - And is transparent to protocol bridges.
- Goal: Drop in replacement for key transfer in clear
  - Customer can decide which to use
    - E.g., check this box to use encryption for keys sent to device
  - Defends against eavesdropper, but not active attacker

Design Constraint: Keep it Simple

- Make it possible to implement in reasonable amount of time
  - And complete the specification in reasonable amount of time ☺
- No Authentication
  - Authentication identities and credentials violate drop-in replacement
  - TCG and others have or will develop authentication protocols
    - This proposal can support other authentication protocols
  - No certificates: let others play in this tarpit
- No Additional Authorization or Access Control
  - Preserve SSC-3 model of what allows an initiator to key a device
  - Ability to send SCSI commands can imply significant authorization (and possibly transport-level authentication)
    - FC zoning, LUN mapping/masking, iSCSI authentication, FC-SP authentication
- No copy manager support (not in SSC-3 either)

Functionality Outline

1. Algorithm and Parameter Selection
   - Crypto algorithms, key sizes
2. Key Exchange
   - Create a shared secret key that an eavesdropper can't see
3. Key Derivation
   - Based on key exchange, create keys for encryption, integrity of wrapped keys
4. Wrap Device encryption key(s)
   - Encrypt, add integrity check, sequence number
5. Send Wrapped Keys to Device
6. Decrypt and Verify
   - Verify: Integrity check, replay prevention

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Functionality Realization: Significant IETF IPsec Reuse

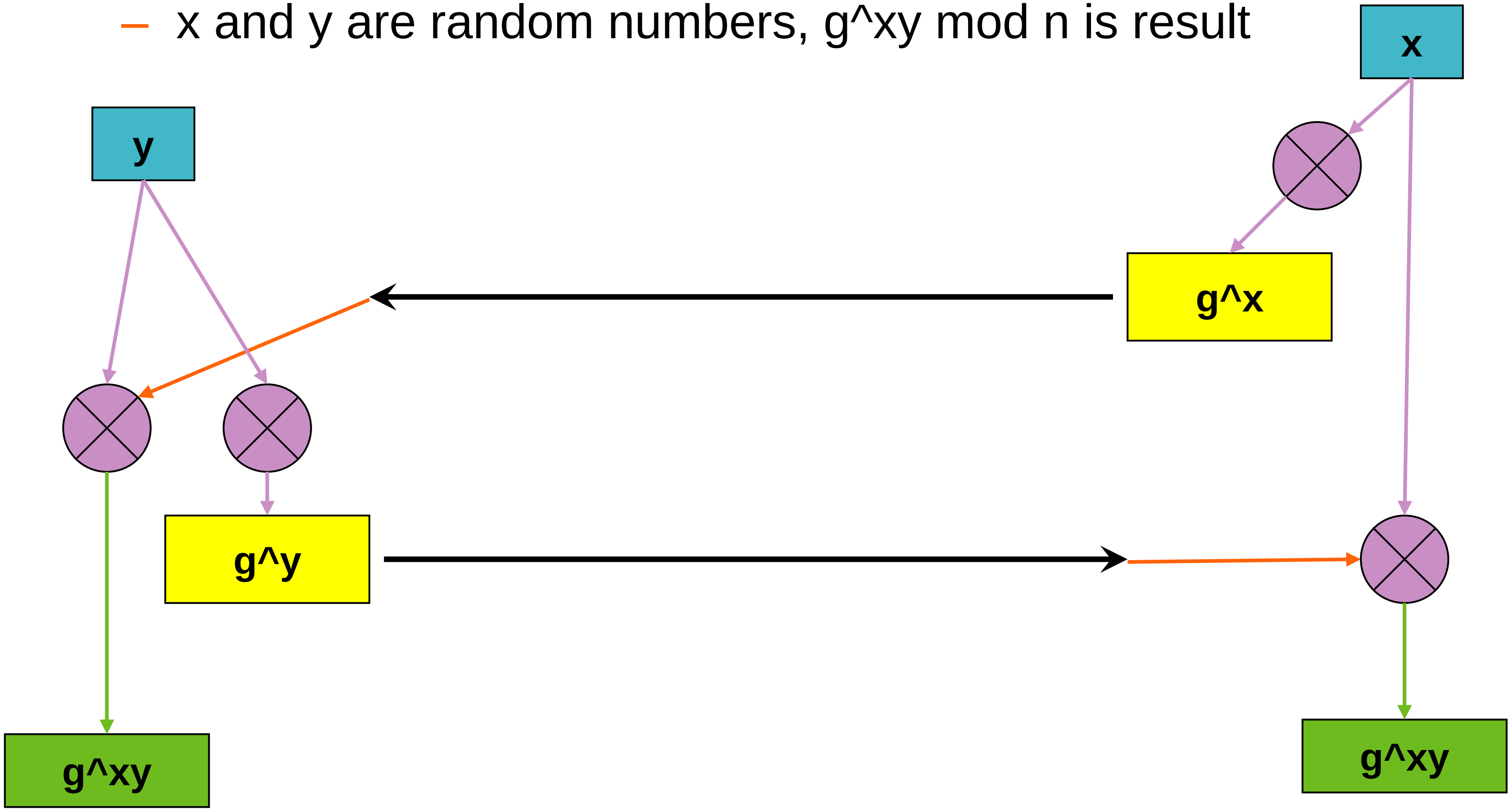
1. Algorithm and Parameter Selection
   - Device server announces algorithms and parameters
2. Key Exchange
   - Diffie-Hellman phase of IPsec IKEv2 (IETF RFC 4306)
3. Key Derivation
   - IPsec IKEv2 key derivation (IETF RFC 4306)
4. Wrap Device encryption key(s)
   - IPsec ESP (IETF RFC 4303) [Alternative: NIST AES Key Wrap (06-225r0)]
   - AES-GCM (IETF RFC 4106) will be one algorithm, AES CCM is another possibility
5. Send Wrapped Keys to Device
   - SECURITY PROTOCOL OUT with new Key Format value
6. Decrypt and Verify
   - Based on ESP (IETF RFC 4303) [Alternative: NIST AES Key Wrap]

Algorithm and Parameter Selection

- Announcement by Device Server
  - There are a few required options
  - Device server picks one of each and announces them
  - Avoids complex negotiation mechanisms
  - Avoids defending against man-in-the-middle downgrade
- What is (currently) announced (6 x 16-bit numbers):
  1. Protocol version number (of this protocol)
  2. Diffie-Hellman group for Key Exchange
  3. Pseudo-random function for Key Derivation
  4. Encryption Algorithm
  5. Key Length for Encryption Algorithm
  6. Integrity Algorithm (not used with combined-mode encryption)
- Announcement includes all important IKEv2 parameters
  - Issue: Prefer not to change to initiator choosing from device capabilities

Diffie-Hellman Key Exchange

- Based on discrete log problem:
  - Given g^x mod n, hard to compute x when n is a large prime
  - x and y are random numbers, g^xy mod n is result



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Proposed Key Exchange

- Nonces passed along with Diffie Hellman values
  - Nonce = Freshly-generated truly random number
  - Nonces allow DH values to be reused
- Device Server generates SPI to identify resulting keys
  - SPI = Security Parameters Index
- Two SCSI commands accomplish the key exchange:
  1. SECURITY PROTOCOL IN (proposed to page 12h)
  2. SECURITY PROTOCOL OUT (proposed to page 12h)
  - Same commands handle algorithm and parameter announcement
  - No payload diagrams yet (sorry)
- Proposed Diffie-Hellman Groups
  - 2048-bit and 3072-bit (IETF RFC 3526)

Key Derivation

- Result of DH Key exchange is not an encryption key
  - Large number with low relative entropy (randomness)
  - 2048-bit result has less than 128 bits of randomness
- Encryption needs high relative entropy key
  - At least 100 bits for 128 bit key
- Key Derivation spans this gap
  - Keyed pseudo-random function compresses nonces and result of DH key exchange to produce required session key(s)
  - Can produce multiple session keys from single exchanged key
- Proposed pseudo random functions
  - HMAC_SHA1, AES_XCBC (IETF RFC 2104, 3664)

Wrap Device Encryption Keys

- Encapsulation Format: IPsec ESP (IETF RFC 4303)
  - Adds SPI, Sequence Number, Initialization Vector (IV) and Integrity Check Value (ICV) to encrypted Key
- Alternative: NIST AES Key Wrap (See Matt Ball's 06-225r0)
- Encryption Algorithms: AES-GCM (IETF RFC 4106)
  - Galois Counter Mode
  - Combined mode: Single pass encrypts and generates ICV
  - Efficient: ICV is significantly less computation than a secure hash integrity check (e.g., HMAC_SHA1)
- Need to pick a second algorithm
  - Proposal: AES-CCM (IETF RFC 4309)
  - Another combined mode, simpler specification and implementation
  - AES-GCM and AES-CCM are the proposed IEEE P1619.1 tape encryption algorithms

Send Wrapped Keys, Decrypt and Verify

- Define Key Format 02h as ESP-wrapped keys
  - Use the SECURITY PROTOCOL OUT command to send
- Anti-replay: Sequence numbers shall be used in order
  - Device server rejects any out-of-order usage
    - Alternative: IPsec-like small window of acceptable sequence numbers
  - Sequence number at device server only advances when decrypt and verify succeeds
- Decrypt and Verity
  - AES-GCM or AES-CCM and its integrity check
  - Discard results if integrity check fails

Adding Additional Keying Algorithms

- SPI links key generation to usage
  - Can use other key generation algorithms
  - Device Server has to ensure that SPI's are unique
  - NIST AES Key Wrap can use same SPI space as ESP
- Some authentication algorithms can generate keys
  - TCG is a likely source
- Requirements on additional keying algorithms
  - Specify key exchange, key derivation, and how device server supplies SPI to initiator
- Device server only has to associate session (ESP) keys and ESP parameters with SPI
  - Can forget how keys were generated after generation is done.

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