Packet Level Authentication (PLA) to protect network infrastructure

Protecting network infrastructures with strong cryptographic algorithms

The concept of Packet Level Authentication (PLA)

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Agenda

- Technology enhancements
- Fundamental design flaws of Internet
- Four technical levels to protect Internet
- Protecting network infrastructure
- PLA:
  - Packet Level Authentication –project
  - Project goals
  - Main operating idea
  - Performance estimations
  - Applications
- Conclusions

Technology enhancements

~100 years

The same thing has happened in Internet in 10 years!

Fundamental design flaws of Internet
Packet Level Authentication (PLA) to protect network infrastructure

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Internet

- Internet was originally designed to survive nuclear war

- Packets can be rerouted quickly

- ... but one mole can damage the routing

- ... or fill network with garbage ...

- ... or corrupt transmitted data

Four technical levels to protect Internet
Four technical levels to protect Internet

1. Reliably operating network infrastructure
   - "Network-traffic-police" supervises traffic that networks operate and users/computers are following the traffic-rules

2. End-to-end secured communication
   - Unauthorized entities can't see or change the content or know with whom we are communicating, and where we are

3. Content integrity/authenticity/timelyness
   - Automatic detection of forged information
   - Originator of WWW-page or email message can be verified
   - Integrity of the message can be verified

4. Virtual communities
   - Only the "good guys" are members of the community
   - Communication is possible only between members
   - Misusers will be removed and punished

Protecting infrastructure:

- Target
  - Communication between two legitimate computers shall work in all the time
  - despite any hostile attacks, that manipulate packets, jam the network, cut the communication links, or by other means try to disturb legitimate communication

  - The network (i.e., routers) shall distinguish whether a packet is
    - generated by a legitimate computer (and packet shall be forwarded further)
    - generated or modified by attackers (record/discard that packet and optionally rise an alarm)

- Network shall be capable of prioritizing traffic based on importance of packets (Qos) and user
  - not every computer or packet is equal

PLA:
Packet Level Authentication-project

History

- PLA-concept was originally introduced in 007-project by end of 2002.
  - Project was funded by Finnish Defence Forces
  - Original idea was to protect wireless communication in military grade wireless ad hoc networks

- Log of publicity:
  - May 2003: First public presentation of the idea at KTH
  - April 2004: Proof-of-concept implementation demonstration SFW2004
  - May 2006: Second proof of concept made as part of the PLA-project outputs

- No patents filed!
PLA-project

- Strategic 2-year research project, 100%-ly Tekes funded (1.1.2006-)
- Four research topics:
  - Architecture
    - Concept design, scalability issues, Internet-wide deployment
  - SW implementation
  - Proof-of-concept with Linux-based routers
  - Crypto-methods
    - Optimized crypto-algorithms for PLA (e.g., elliptic curves)
  - HW acceleration
    - FPGA-based implementation of crypto-algorithms
- Three research groups from HUT
  - prof. Hannu H. Kari (mobility management, architecture, SW implementation)
  - prof. Kaisa Nyberg (crypto-algorithms, security analysis)
  - prof. Jorma Skyttä (crypto-accelerator, FPGA-implementation)

Original concept of PLA

With PLA:
- Interference is stopped at the first node

Without PLA:
- Enemy uses our nodes to disturb our network

Original concept of PLA

With PLA:
- Discard illegal duplicates

Without PLA:
- Illegal duplicates cause flooding

PLA: Project goals

- To guarantee packet integrity
  - Undeniable proof of the origin of the packet
- To protect network infrastructures
  - Internet, in general
  - Wireless ad hoc networks, especially
  - Military networks, definitely
- Guarantee, that good packets can go through the network
  - Malicious packets shall be eliminated promptly
- PLA-solution should be part of every computer in the future

Packet level authentication

- Analogy:
- Security measures on notes
  - Holograms
  - Microprint
  - Watermarks
  - UV-light
  - ...
- Any receiver of notes can verify the authenticity of every note without consulting with banks or other authorities
Packet level authentication

**Packet level authentication**

- How about IP world?
  - Each IP packet should have similar security measures
    - Receiver (e.g., a router) of a packet must be capable of verifying the authenticity of the IP packet without prior security association with the sender
      - i.e., receiver must be sure that the packet is sent by a legitimate node and the packet is not altered on the way
      - Just like with notes, each IP packet shall have all necessary information to verify authenticity
    - In addition,
      - Since IP packets can be easily copied, we must have a mechanism to detect duplicated and delayed packets

**Why not IPsec?**

- Benefits of IPsec
  - Fast crypto algorithms and packet signatures due to symmetric keys
  - Well tested implementations and protocols
- Disadvantages of IPsec
  - Can’t handle compromised nodes
  - IPsec is end-to-end protocol, intermediate nodes can’t validate packets
  - Requires several messages to establish security association between nodes
  - Scales badly to very dynamic networks

PLA: Main operating idea

- PLA header inserted the same way as Mobile IP, IPsec, ... protocols
- PLA header is transparent to standard IP routers (that do not understand PLA)
- PLA header is transparent to all upper level protocols (UDP, TCP, SCTP, ...)
- PLA can be used in both IPv4 and IPv6 networks

Packet level authentication: Implementation

- Extra header per packet
  1. Authority
     - General, TTP, Access-network operator, home operator,...
  2. Public key of sender
     - E.g., Elliptic curve (ECC)
  3. Authority’s signature of sender key and validity time
     - Authority’s assurance that the sender’s key is valid for a given time period
  4. Sending time (+sequence number)
     - Possibility to remove duplicates and old packets
  5. Signature of the sender of this packet
     - Sender’s assurance that he has sent this packet
PLA: Performance estimations

- **Sending node**
  - One digital signature per packet

- **Verifying node/Receiving node**
  - First packet:
    - One certificate validation & One digital signature verification
  - Next packets:
    - One digital signature verification per packet

- Digital signature requires one hash and one elliptic curve operation

Performance

- **Elliptic curve HW implementation at ECE department of HUT**
  - FPGA with 350 000 gates
  - Clock speed 66MHz
  - 167 bit ECC multiplication on 100 µs using 167 bit arithmetics
  - Estimate: one signature in less than 1 ms
    - Actually it is closer to 200 µs
  - Performance is thus (in order of magnitude)
    - 1000 packets/s
      - With 500 Byte packet size, 4 Mbps

- **How about scaling up?**
  - Pentium IV class silicon
  - Clock speed
    - 66MHz -> 3 GHz
      - (speedup factor 45)
  - Dice size
    - 350 000 gates -> 55 M gates
      - (160 parallel signature units)

- **Throughput of "Pentium IV-class" PLA HW accelerator**

<table>
<thead>
<tr>
<th>Signatures validated per packet</th>
<th>Packet size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>150B</td>
</tr>
<tr>
<td>One (*)</td>
<td>8.6</td>
</tr>
<tr>
<td>Two (**)</td>
<td>4.3</td>
</tr>
</tbody>
</table>

(1) For the first packet from a given sender
(2) For the subsequent packets from the same sender

Methods to improve performance

- **Parallel HW (multiple chips)**
- **Sending node**
  - Every packet must be signed by the sender in order to minimize security problems
- **Receiving/Verifying node**
  - Check packets randomly
  - Check only every Nth packet
  - Checking can be adaptive
    - Check fewer packets from trusted nodes
    - Check more packets at the beginning of the stream of packets
    - More packets from same node of a flow, fewer checks done
    - When you feel paranoid, check more
PLA: Applications

Applications for PLA

• Protecting network infrastructures
• Securing wireless ad hoc networks
• Restricting DoS and DDoS attacks
  • I don’t like messages from this sender, block it at nearest router
  • Nearest PLA-capable router to the attacker blocks the traffic
• Handling compromised nodes
• Delegation of command chain
• Reestablishing core network after military strike
• Handling access control
• Replacing firewalls
• Handle charging/accounting

Conclusions

• PLA is part of HUT’s Context Aware Management/Policy Manager (CAM/PM) –architecture, which is a rule based system that adapts node’s behavior according to its surrounding
• Packet level authentication (PLA) provides scalable method to eliminate most of the faulty, forged, duplicated, and otherwise unwanted packets
• PLA can be implemented in HW with gigabits/s authentication capacity for core network routers

Thank you,
Questions?

Some background material
Some PLA details

Packet level authentication

- General requirements
  - Security mechanism shall be based on public algorithms
  - No security by obscurity!
  - Public key algorithms and digital signatures provide undeniable proof of the origin
  - Symmetric keys can’t be used since nodes may be compromised
  - Protocol must be compatible with standard IP routers and applications
  - Standard header extensions shall be used
  - Solution must be robust and scalable

- Advantages
  - Increased packet size (~100 bytes)
  - Requires strong crypto algorithms
  - Elliptic curves, digital signatures, ...
  - More computation per packet
    - One or two digital signatures, one or two hashes per packet

- Disadvantages
  - Increased packet size (~100 bytes)
  - Transmission overhead, processing delays
  - Requires strong crypto algorithms
  - Elliptic curves, digital signatures, ...
  - More computation per packet
    - One or two digital signatures, one or two hashes per packet

Packet level authentication: Implementation

- Sending:
  1. Authority
    - Constant field
  2. Public key of sender
    - Constant field
  3. Authority’s signature of sender key and validity time
    - Constant field
  4. Sending time (+sequence number)
    - Update per packet
  5. Signature of the sender of this packet
    - Calculate per packet

- Reception, 1. packet:
  1. Check sending time
    - Check time
  2. Authority
    - Verify that you know the authority (or ask your authority is this trustworthy)
  3. Public key of sender
    - Store this
  4. Authority’s signature of sender key and validity time
    - Check validity
  5. Signature of the sender of this packet
    - Verify
  6. Sequence number
    - Store sequence number

- Reception, next packets:
  1. Sending time
    - Verify time and sequence numbers
  2. Authority
    - Verify data in cache
  3. Public key of sender
    - Verify data in cache
  4. Authority’s signature of sender key and validity time
    - Verify data in cache
  5. Signature of the sender of this packet
    - Verify
  6. Store time and sequence number
Open Software Research - principle

Test environment

Test environment: PLA operations

Context Aware Management/Policy Manager (CAM/PM) architecture
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New solution

- Context Aware Management/Policy Manager
  - Each node (computer) has a rule based policy manager that controls the behavior of the node and adapts it to environment changes
- Adaptive trust model
  - Trust on nodes is not static but changes on time
- Packet level authentication
  - A mechanism to ensure that only correct and authentic packets are timely processed

Context Aware Management/Policy Manager

- Context Aware Management layer
  - Interfaces with all protocol layers and applications
- Policy Manager
  - Decisions are based on policy rules
  - Collects information from all protocol layers and applications
  - May have local user interface
  - Can negotiate with neighboring PMs or take commands from remote entity
- Policy rules
  - Formal representation of decision methodology
  - New rules can be sent by authorized entity (e.g., owner of the node, civil/military authority)

Utilizing CAM/PM with PLA and adaptive trust model:
New rules to fix damaged core network with wireless network

Application: New core network:
Military strike

Application: New core network:
Reconfiguration
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Utilizing CAM/PM with PLA and adaptive trust model: Fast communication in a dynamic wireless network

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Application: New core network: After military strike

Utilizing CAM/PM with PLA and adaptive trust model: Detecting replayed packets

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Application: Quick secured communication in battle field

Utilizing CAM/PM with PLA and adaptive trust model: Detecting malicious behavior and revoking nodes

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Application: Restricting DoS attack
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Application:

Excluding compromised nodes

Utilizing CAM/PM with PLA and adaptive trust model:
Combining two ad hoc network organizations

Application:

Delegation of command chain
Application: Delegation of command chain

Utilizing CAM/PM with PLA and adaptive trust model: Handling compromised nodes

Application: Revocation of large quantity of nodes

Application: Revocation of large quantity of nodes

Application: Revocation of large quantity of nodes