Military grade wireless ad hoc networks

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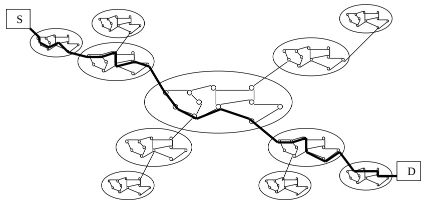
Agenda

- **Internet**
- **Privacy**
- **Problems in military grade wireless ad hoc networks**
- **Problem statement**
- **Requirements**
- **Security levels**
- **Current and new solutions**
- **Layered model for wireless networks**
- **Context Aware Management/Policy Manager (CAM/PM)**
- **Packet Level Authentication (PLA)**
- **Applications**
- **Performance**
- **Conclusions**

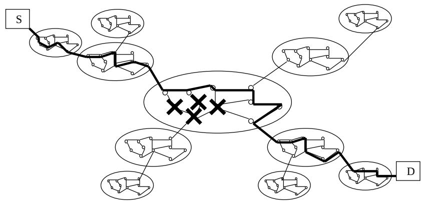
Internet

- **Internet was designed to survive nuclear war**



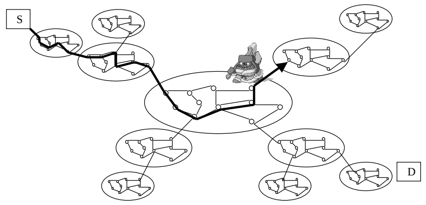
Internet

- **Packets can be rerouted quickly**



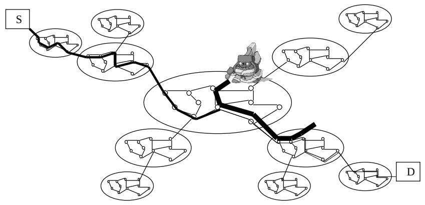
Internet

- **...but one mole can damage the routing**



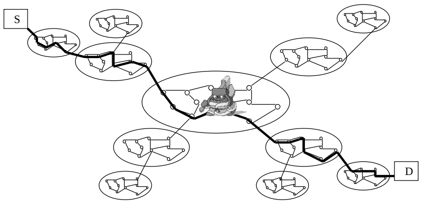
Internet

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



Internet

- ...or corrupt transmitted data



Internet

- Problems are dramatically getting worse, when
  - wireless networks are used instead of wired links
  - dynamic network infrastructure is used instead of static
  - nodes are mobile
  - environment is hostile
  - nodes may become compromised
  - strict Quality of Service requirements are needed
  - transmission channel has very limited capacity

Privacy

- Definition of Privacy

> *Privacy is the claim of individuals, groups, and institutions to determine for themselves, when, how, and to what extent information about them is communicated to others.*
>
> Alan Westin 1967

6...7 categories of privacy

- Data privacy (content)
- Identity privacy (source/destination)
- Location privacy (place)
- Time privacy (when)
- Privacy of existence (does it exist)
- Transactions (something that has been agreed)
- 7th category?
  - Property (I have this feature)

Problems in military grade wireless ad hoc networks

- Hostile environment
- Enemy
- Privacy
- Routing
- Security
- Quality of service
- Performance
- Compromised nodes
- Dynamicity
- Life time of nodes
- Reliability
- Costs
- Inequality of nodes
- ...

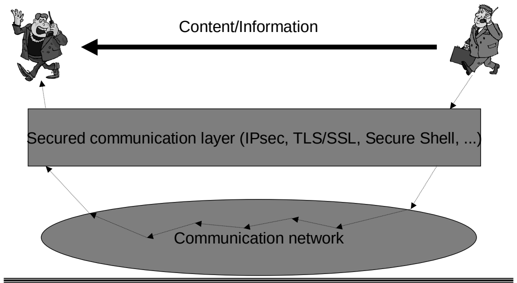
Problem statement

- How to ensure
  - the privacy
    - of communication
  - in military grade
    - wireless
      - ad hoc networks

Problem statement

- How to ensure
  - the privacy (data, identity, location, time, existence)
    - of <u>(reliable)</u> communication
  - in military grade (<u>hostile environment</u>, compromised nodes, high casualty rate)
    - wireless (eavesdropping, <u>disturbance</u>, unreliable links)
      - ad hoc networks (<u>no static infrastructure</u>, <u>mobile nodes</u>, <u>dynamic routing</u>)

3 levels of security


Content/Information
Secured communication layer (IPsec, TLS/SSL, Secure Shell, ...)
Communication network

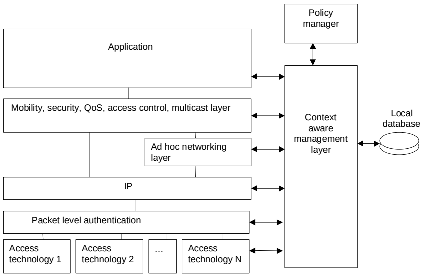
Current solutions

- Application level security
  - PGP, Secure Shell, ...
- Network level security
  - IPsec
- Link level Security
  - WEP, A5,...

New solution

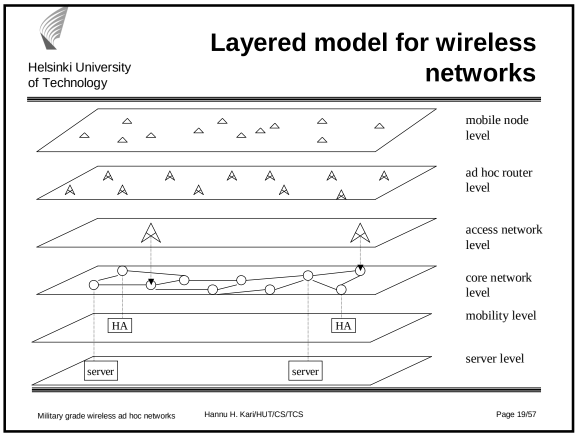
- Context Aware Management/Policy Manager
  - Each node (computer) has a rule based policy manager that controls the behavior of the node and adapts it to environment changes
- Adaptive trust model
  - Trust on nodes is not static but changes on time
- Packet level authentication
  - A mechanism to ensure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

Context Aware Management/ Policy Manager



Context Aware Management/ 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)



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Layered model for wireless networks

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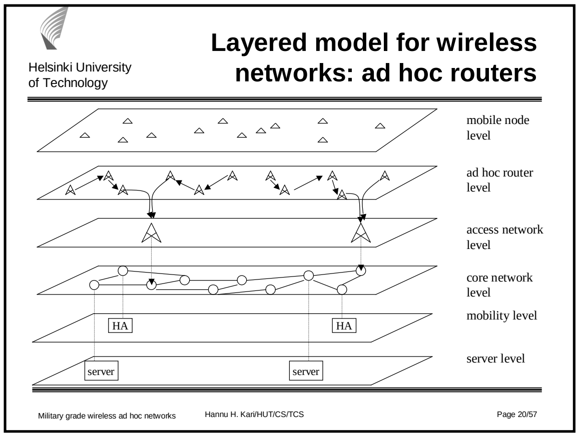

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Layered model for wireless networks: ad hoc routers

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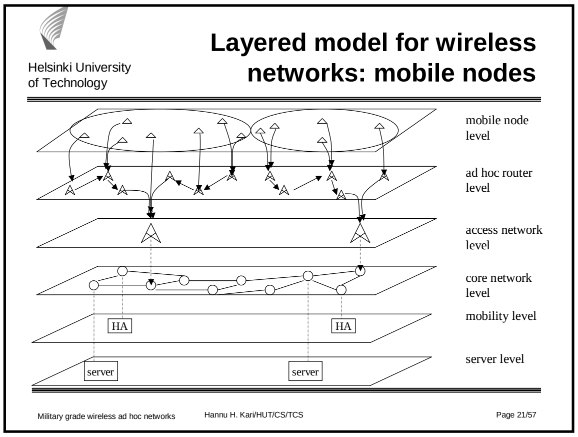

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Layered model for wireless networks: mobile nodes

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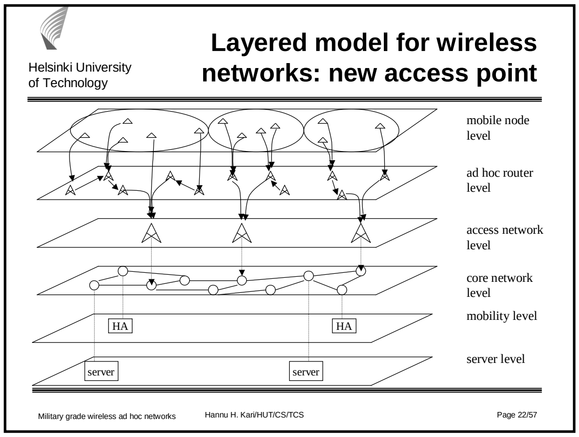

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Layered model for wireless networks: new access point

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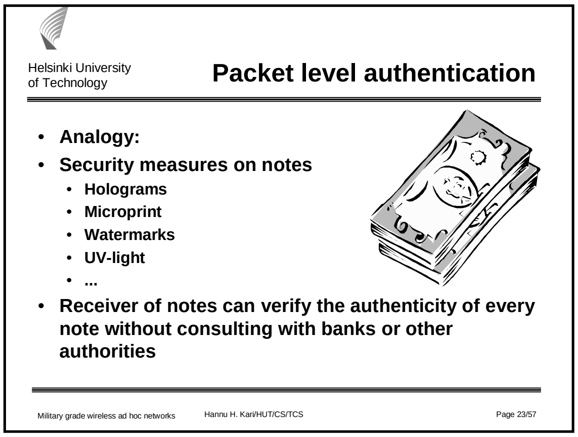

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Packet level authentication

- **Analogy:**
- **Security measures on notes**
  - **Holograms**
  - **Microprint**
  - **Watermarks**
  - **UV-light**
  - **...**
- **Receiver of notes can verify the authenticity of every note without consulting with banks or other authorities**

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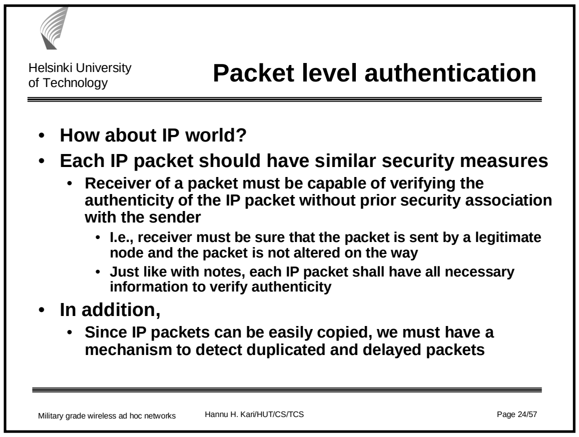

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Packet level authentication

- **How about IP world?**
- **Each IP packet should have similar security measures**
  - **Receiver 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**

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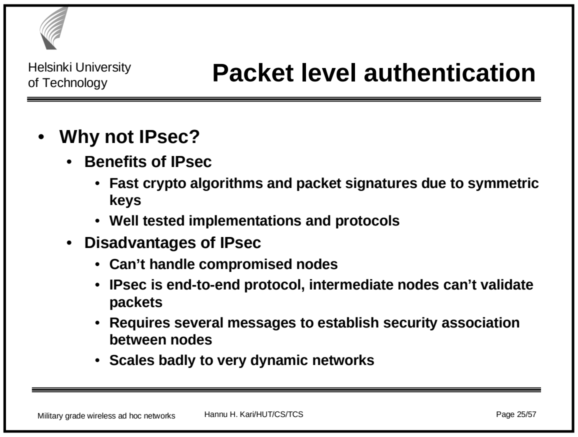
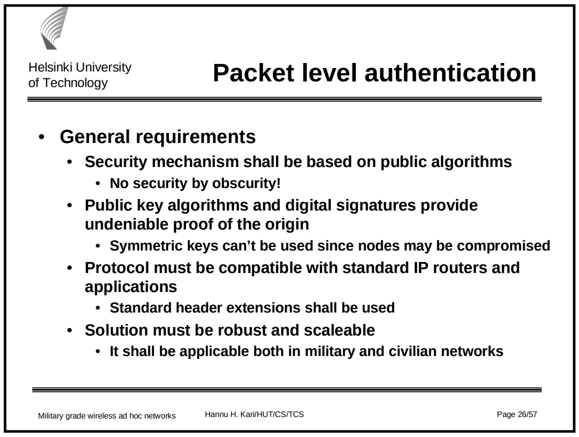


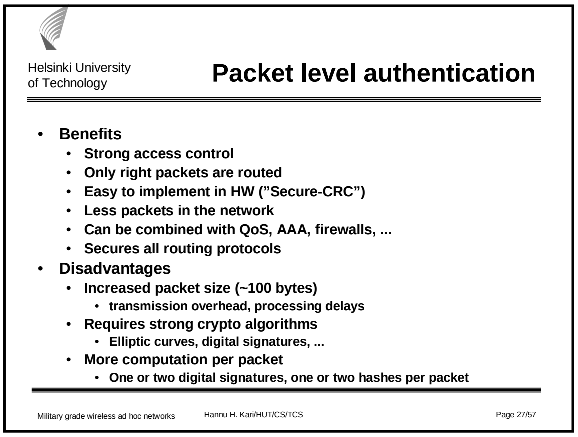
Packet level authentication

- 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



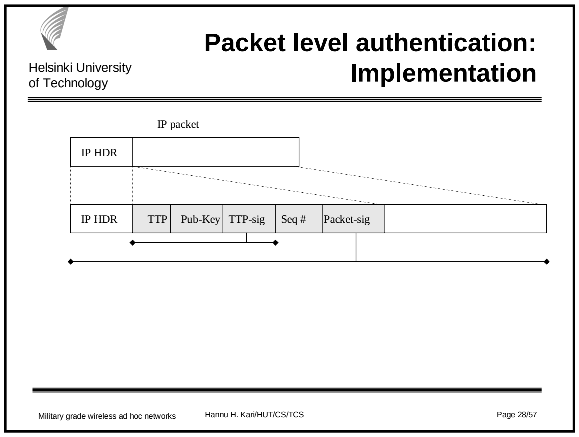
Packet level authentication

- 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 scaleable
    - It shall be applicable both in military and civilian networks

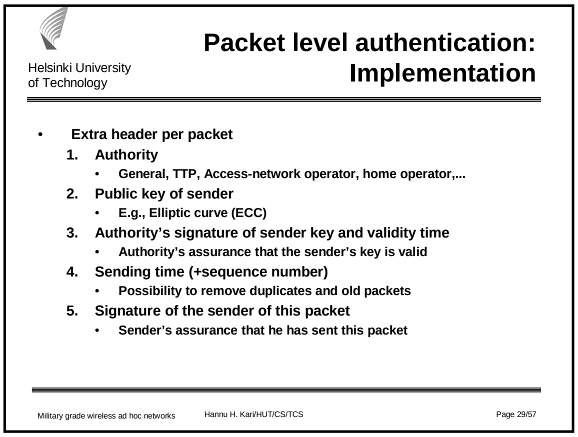


Packet level authentication

- Benefits
  - Strong access control
  - Only right packets are routed
  - Easy to implement in HW (”Secure-CRC”)
  - Less packets in the network
  - Can be combined with QoS, AAA, firewalls, ...
  - Secures all routing protocols
- 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

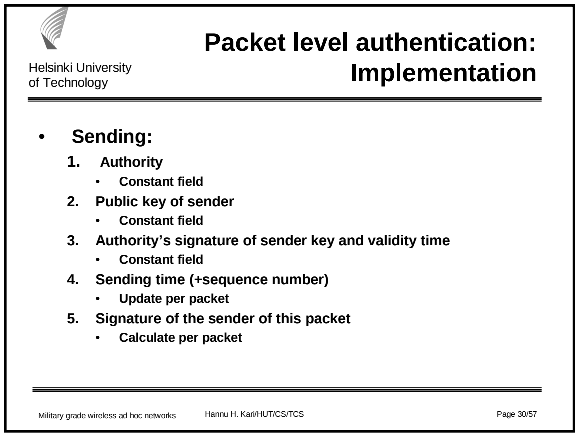


Packet level authentication: Implementation



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
  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



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

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Packet level authentication: Implementation

- 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

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Packet level authentication: Implementation

- 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

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Applications for PLA

- Securing wireless ad hoc networks
- Restricting DoS and DDoS attacks
- Handling compromised nodes
- Delegation of command chain
- Reestablishing core network after military strike
- ...
- Handling access control
- Replacing firewalls
- Handle charging/accounting

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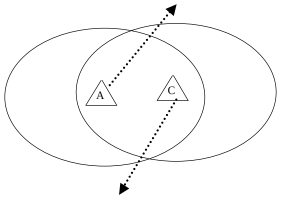
Purpose of PLA

- Fast negotiation of secured communication of fast moving mobile nodes



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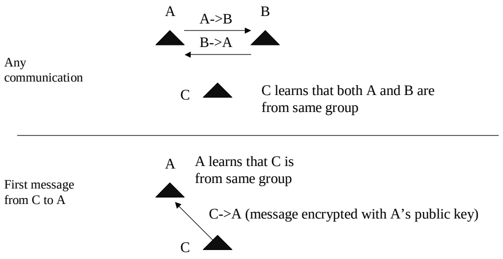
Application: Quick secured communication in battle field



Any communication

C learns that both A and B are from same group

First message from C to A

A learns that C is from same group

C->A (message encrypted with A's public key)

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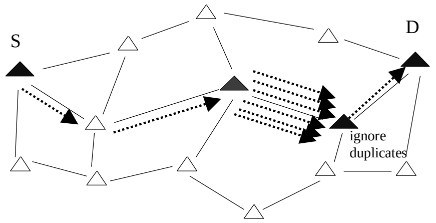
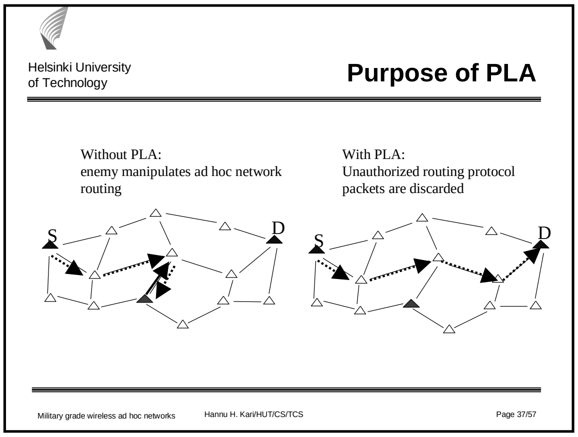
Application: Restricting DoS attack





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Purpose of PLA

Without PLA:
enemy manipulates ad hoc network routing

With PLA:
Unauthorized routing protocol packets are discarded

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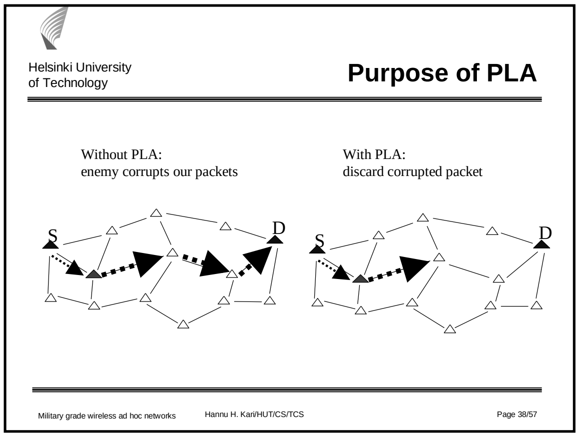

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Purpose of PLA

Without PLA:
enemy corrupts our packets

With PLA:
discard corrupted packet

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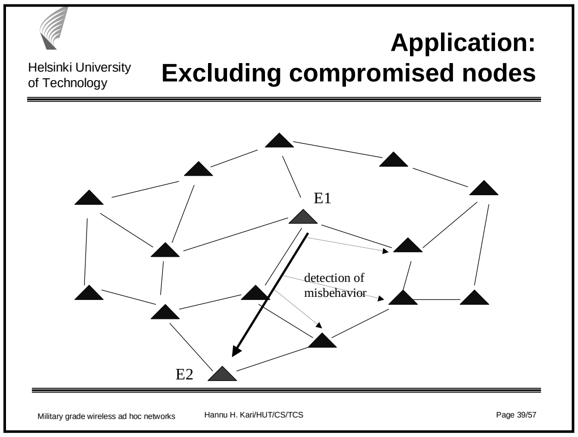

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Application: Excluding compromised nodes

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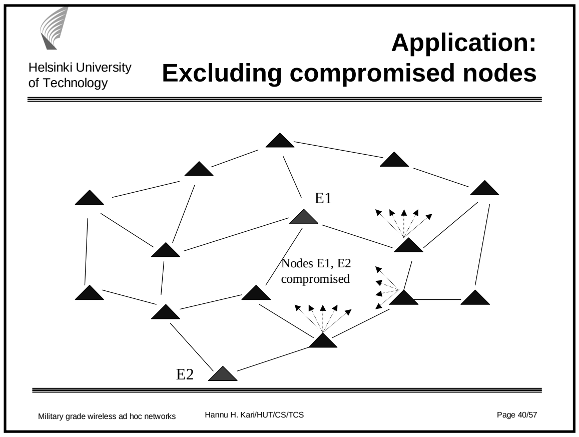

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Application: Excluding compromised nodes

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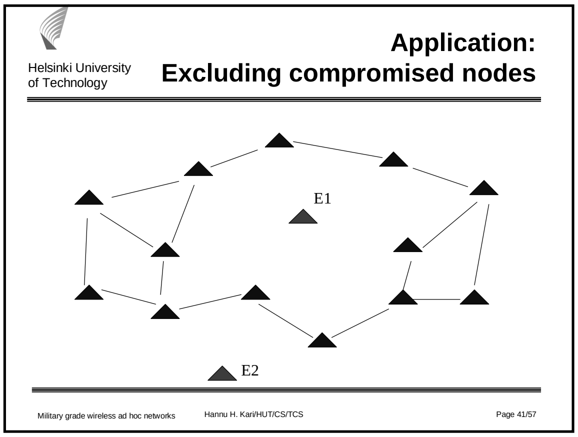

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Application: Excluding compromised nodes

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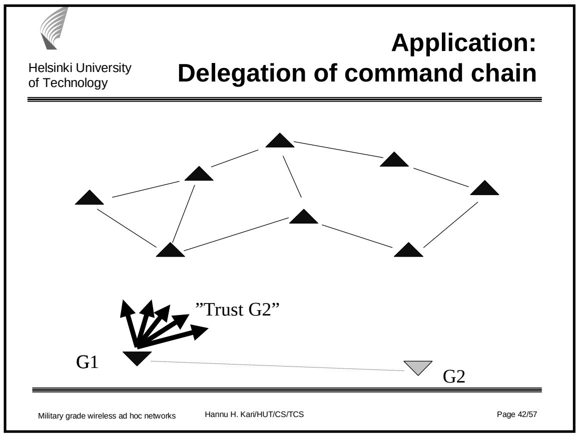

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Application: Delegation of command chain

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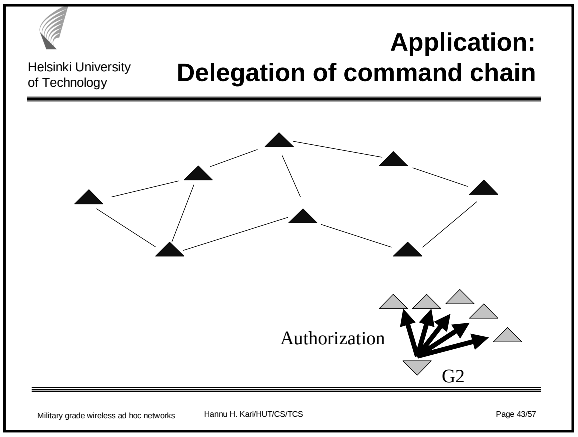

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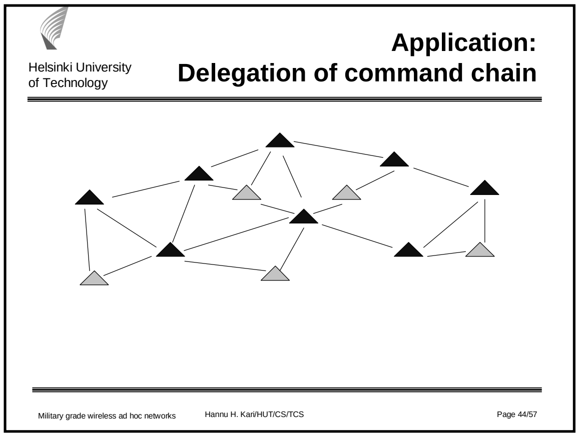
Application: Delegation of command chain



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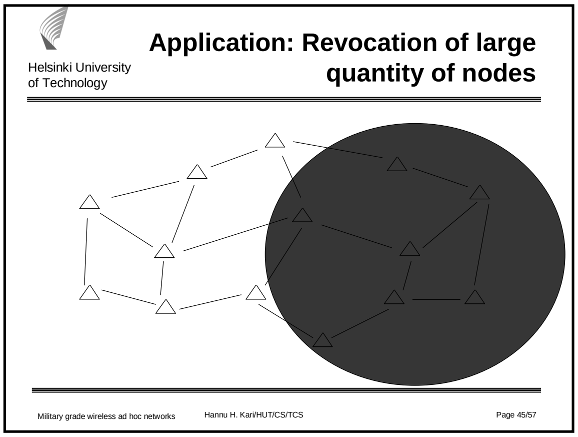
Application: Delegation of command chain



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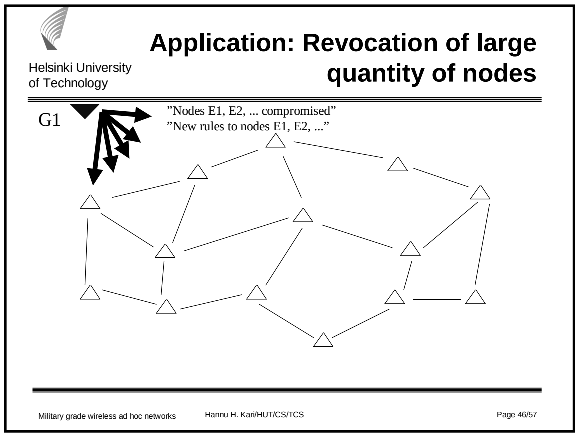
Application: Revocation of large quantity of nodes



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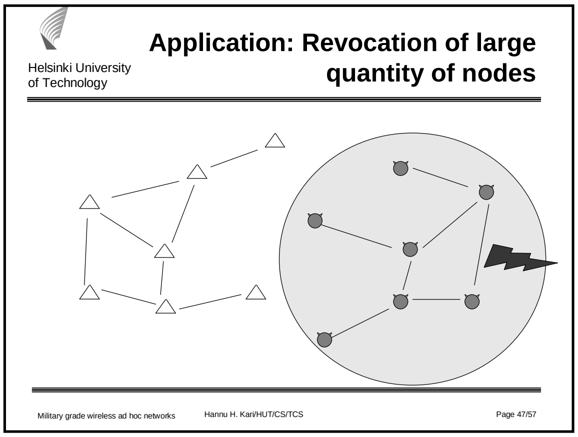
Application: Revocation of large quantity of nodes

”Nodes E1, E2, ... compromised”
”New rules to nodes E1, E2, ...”



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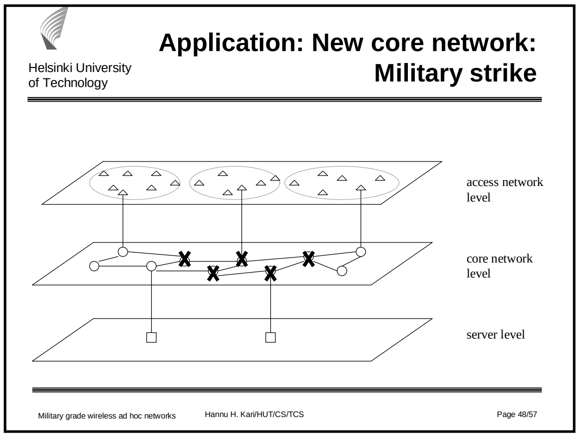
Application: Revocation of large quantity of nodes



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Application: New core network: Military strike

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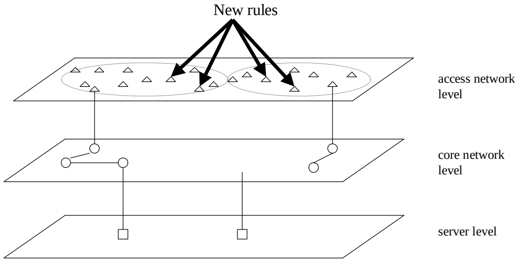
Application: New core network: Reconfiguration



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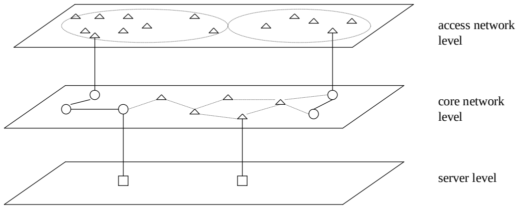
Application: New core network: After military strike



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Performance

- **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**

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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**
  - **one signature in less than 1 ms**
- **Performance is thus (in order of magnitude)**
  - **1000 packets/s**
    - **With 500 Byte packet size, 4 Mbps**

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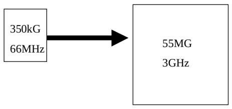
Performance

- **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)**



$$\frac{1}{1ms}\times\frac{C_{new}}{C_{ref}}\times\frac{G_{new}}{G_{ref}}=\frac{1}{1ms}\times\frac{3GHz}{66Mhz}\times\frac{55\,000\,000}{350\,000}=7.14\,Msignature/s$$

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Performance

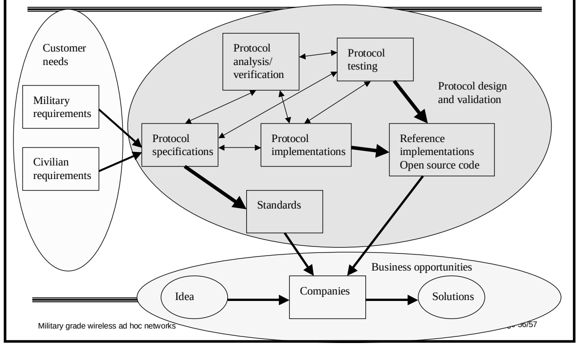
- **Throughput of "Pentium IV-class" PLA HW accelerator**

Throughput [Gbps]			
Signatures	Packet size		
validated			
per packet	150B	500B	1500B
One (*)	8.6	28.6	85.7
Two (**)	4.3	14.3	42.9
(**) For the first packet from a given sender			
(*) 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

Operating model for open source research



Conclusions

- Context Aware Management/Policy Manager (CAM/PM) -architecture is 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