T-79.192 Special Course in Theoretical Computer Science

Military grade wireless ad hoc networks

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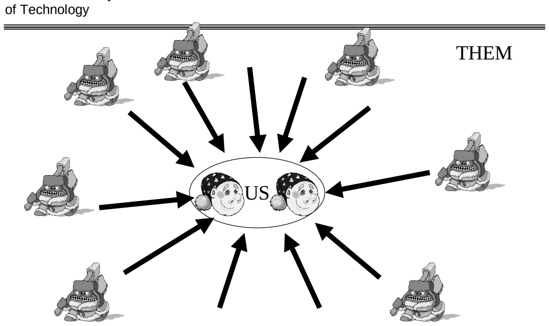
Topics

- **Problem statement**
- **Privacy issues**
- **Communication**
- **Trust**
- **Background information**
- **Sun Tzu**
- **Problems in military grade wireless ad hoc networks**
- **Requirements**
- **Security levels**
- **CAM/PM**
- **Military/Civilian networks**
- **Packet level authentication**



Problem statement

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

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What is privacy?

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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

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5 categories of privacy

- **Data privacy (Informaatio)**
- **Identity privacy (Kohde/lähde)**
- **Location privacy (Tapahtumapaikka)**
- **Time privacy (Tapahtuma-aika)**
- **Privacy of existence (Olemassaolo)**

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What is communication?

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Communication

- What is communication?
  - Exchange/deliver of information
    - Fetch information
    - Send information
    - Send commands
    - Delegation of rights
    - Friend or Foe?
- Modes of communication
  - Human-human
  - Human-computer
  - Computer-computer

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What is trust?

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Trust

- What is trust?
  - Belief that other party acts as agreed
- Form of trust
  - Trust on
    - Indentity
    - Information
    - Timeliness
- Transitivity of trust
- Concept of incomplete trust

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Trust

- A trusts B to perform operation X with probability 75%
  - T(A, B, X) = 0.75
- B trusts C to perform operation X with probability 50%
  - T(B, C, X) = 0.50
- A trusts C (via B)
  - T(A, C, X) = f (T(A, B, X), T(B, C, X))
    ≅ T(A, B, X) * T(B, C, X)

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Trust

- **A trusts C (via others)**
  - **$T(A, C, X) = \Sigma f(T(A, i, X), T(i, C, X)), i \neq A,C$**
- **Iterative trust of A to C**
  - **$T_{i+1}(A, C, X) = \alpha T_i(A, C, X)+(1- \alpha)\Sigma f(T(A, i, X), T(i, C, X)), i \neq A,C$**

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Trust

- **Normalizing trust**
  - **A learns that B tells the time always in 2 minutes later than others**
    - **B is trustworthy, but 2 minutes must be added to its time estimate**

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Background information

- **Wired and wireless networks**
  - **Multitude of access technologies**
- **IPv4 and IPv6**
- **Routing protocols**
- **Mobility management**
  - **Mobile IP and HIP**
  - **Ad hoc routing protocols**
  - **Hierarchical networks**
- **Security**
  - **Ipsec, Secure shell, SSL**
  - **PKI certificates**
- **Adaptive applications**

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Sun Tzu: The Art of War

- **Military action is important to the nation
it is the ground of death and life,
the path of survival and destruction.**
- **Five things are**
  - **Way**
  - **Weather**
  - **Terrain**
  - **Leadership**
  - **Discipline**

Sun Tzu: "The Art of War", 6th century BC

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What are problems in military grade wireless ad hoc networks?

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Problems in military grade wireless ad hoc networks

- Hostile enemy
- Privacy
- Routing
- Security
- Quality of service
- Performance
- Compromised nodes
- Dynamicity
- Life time of nodes
- Reliability
- Costs
- Unequality of nodes

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Difference between military & civilian networks?

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Military network requirements

- Military environment is the most difficult for the mobile communication and mobility management
  - Hostile enemy
  - Radio power usage restrictions
    - battery, reveal location, time, and importance of the node
  - Trust models
    - Handling of compromised nodes
  - Quality of service control
    - Not all nodes or packets are equal
  - Need for robustness
    - Fault resilience, automatic repair after failure, redundant routes
  - Need for performance

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Military network requirements

- **Design goal to handle:**
  - **Two fast moving mobile nodes communicating in a military-grade network using partially ad hoc -formed wireless access networks**
- **Properties**
  - **Ultra frequent mobility (10 times/s), multipath routing**
  - **Mobility management is tightly coupled with security**
  - **QoS provided with security**
  - **Access control coupled with security**
  - **Ad hoc network needs to have security and mobility combined to route data packets**
  - **Ad hoc network provides connection to fixed network**

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Civilian networks

- **What military networks are missing?**
- **In governmental and civilian networks we have**
  - **Cost issue**
    - **Protocols and equipment may not be too expensive**
  - **No black/white relation between nodes**
    - **Not just friend/foe separation**
    - **Own/allies/neutral/enemy**
  - **Limited radio spectrum**
    - **Commercial radio licences**
  - **No predefined trust between nodes**
    - **In military trust is easy to establish but difficult to keep**
    - **In commercial networks trust is difficult to establish but easy to keep**

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3 levels of security

- **Content level security**
- **Transmission security**
- **Network security**

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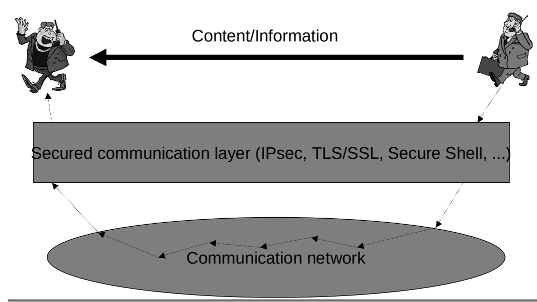
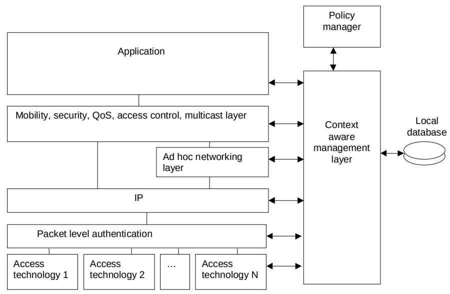
3 levels of security



Context Aware Management/ Policy Manager



CAM/PM

- 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)

Packet level authentication

- Communication shall be based on strong security
  - Authenticity of every packet must be verified before using it
  - Impacts of hostile nodes shall be minimized, especially in the radio network
  - Decisions can be based on the trust level of the information and/or sending node

Packet level authentication

- Packet level authentication (PLA)
  - Every packet can be checked for authenticity, integrity, non-repudiation, timeliness, ...
    - Just like in IPsec
  - Any node in the network can do the PLA checking
    - IPsec requires security association
  - PLA checking requires no previous negotiation or exchange of security parameters between the sender and verifier
    - IPsec can't do this!

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**
- **Disadvantages**
  - **Increased packet size (~60-100 bytes)**
  - **Requires strong crypto algorithms**
    - **Elliptic curves, digital signatures, ...**
  - **More computation per packet**

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 (+sequnce number)**
     - **Update per packet**
  5. **Signature of the sender of this packet**
     - **Caclulate per packet**

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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Packet level authentication: Implementation

- **Routers in the network**
  - **To authenticate a packet, we need a trust on the authority that has authorized the sender**
    - **directly (same authority as ours)**
    - **indirectly (a chain of trust)**
  - **Routers may operate memoryless**
    - **no need for cache memory**
    - **needs more computing power**
    - **saves memory**
    - **possibility to optimize**

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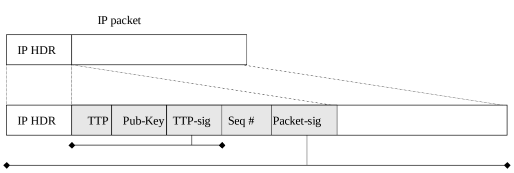
HW implementation



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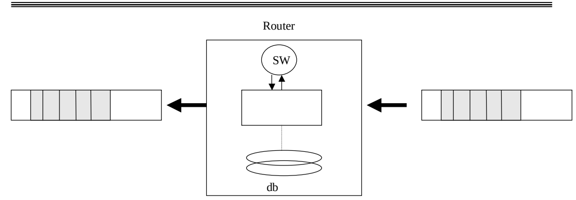
HW implementation



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HW implementation

IP HDR	TTP	Pub-Key	TTP-sig	Seq #	Packet-sig	

1. Check sending time
2. Calculate hash

no-hash

3. Validate TTP
4. Store Pub-Key
5. Verify TTP-sig
6. Verify Packet-sig
7. Store Seq #

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HW implementation

IP HDR	TTP	Pub-Key	TTP-sig	Seq #	Packet-sig	

1. Check sending time
2. Calculate hash

in-hash

3. Validate Seq #
4. Check validity time

5. Verify Packet-sig
6. Store Seq #

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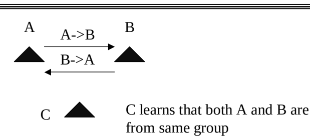
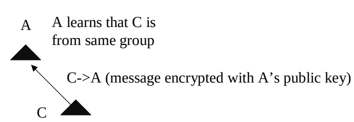
Application: Quick secured communication in battle field

Any communication



First message from C to A



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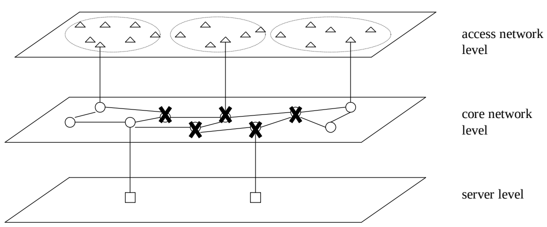
Application: New core network: Military strike



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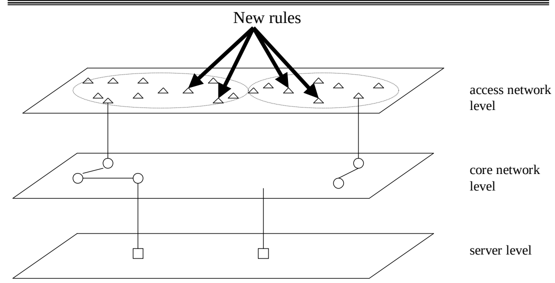
Application: New core network: Reconfiguration



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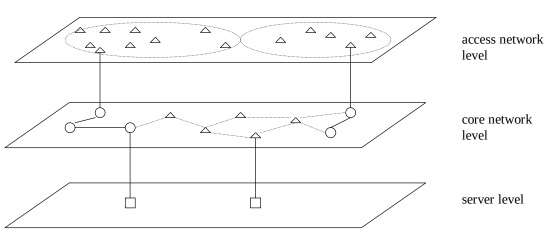
Application: New core network: After military strike



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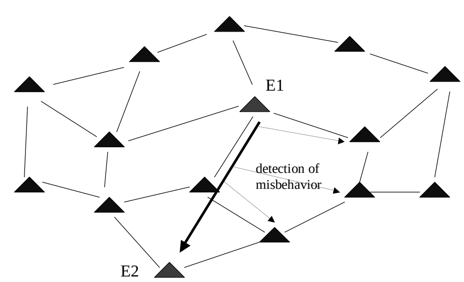
Application: Excluding compromised nodes



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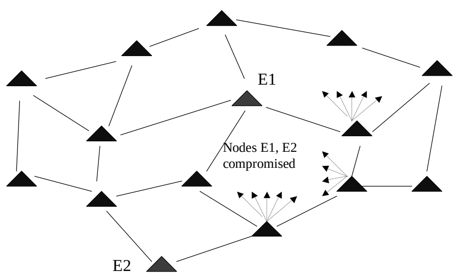

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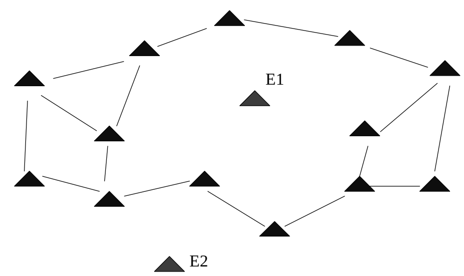
Application: Excluding compromised nodes



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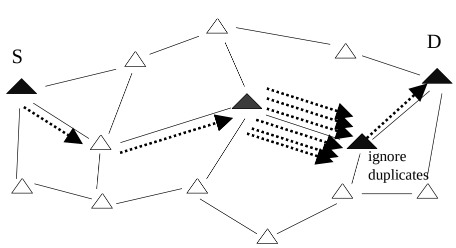
Application: Restricting DoS attack



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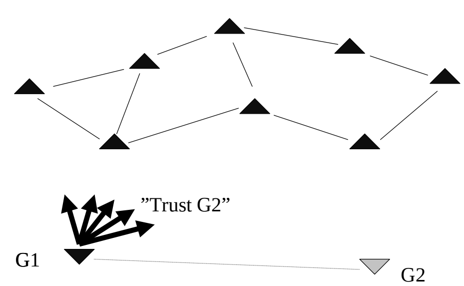
Application: Delegation of command chain



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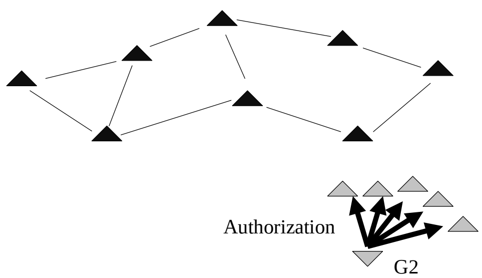
Application: Delegation of command chain



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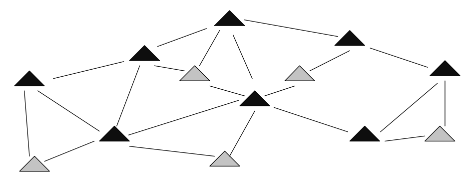
Application: Delegation of command chain



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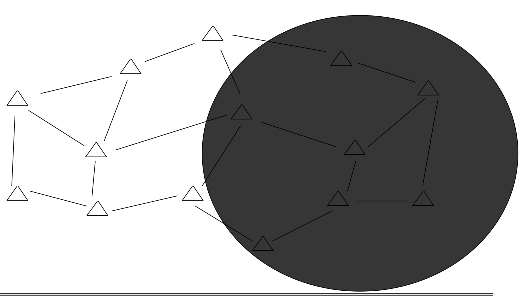
Application: Revocation of large quantity of nodes



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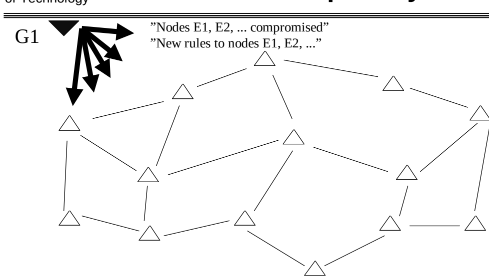
Application: Revocation of large quantity of nodes



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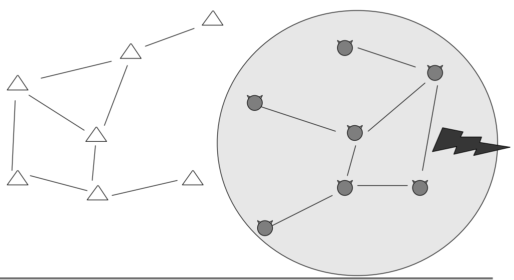
Application: Revocation of large quantity of nodes



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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 operatation
  - HUT's HW implementation performs an ECC multiplication in around 100 microseconds
    - Isn't this enough for sending node?

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Methods to improve performance

- Sending node
  - Include PLA only in every Nth packet
    - ⇒ Potential security problem
  - Include forward credentials in PLA field
    - "I'm going to send X packets in next Y seconds"
- 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

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Time synchronization

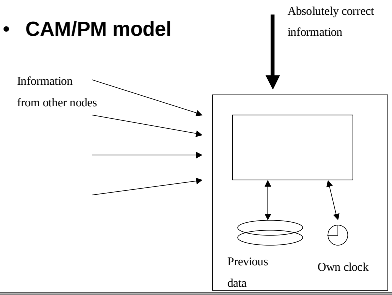
- Needs
  - Common understanding of the time
    - Perform operation at time T
    - Perform operation at T minutes from now
- Methods
  - Initial time synchronization
  - Global time beacon
  - Local time adjustment
    - Concept of incomplete trust and time adjustment

Time synchronization

- Problems
  - PLA and time consistency?
    - Packet rejection
    - Packet replay
  - Required accuracy of time?
  - Monotonically growing time
    - Clocks can't go backwards
    - Can clock stop for a while?
  - Clock inaccuracy
    - Typically in order of 1...10 ppm
  - Inconsistent clock
    - Time warps
  - Large time differences between neighbors

Time synchronization

- CAM/PM model



Location synchronization

- Needs
  - Knowledge of node's own position
  - Geographical operations
    - Routing, node activation, node movement
- Methods
  - GPS, manual configuration, physical attachment
  - radio signal measuments, laser/ultra sound,...
- Problems
  - Moving nodes
  - Accuracy

Securing communication for groups

- Common communication channel
  - For entiry army
- Channel for groups
  - Few nodes or hundreds of nodes
- Key change
  - Peer-to-peer keys, group keys
  - Periodic change
  - Change after compromising nodes