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Military grade wireless ad hoc networks

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Agenda

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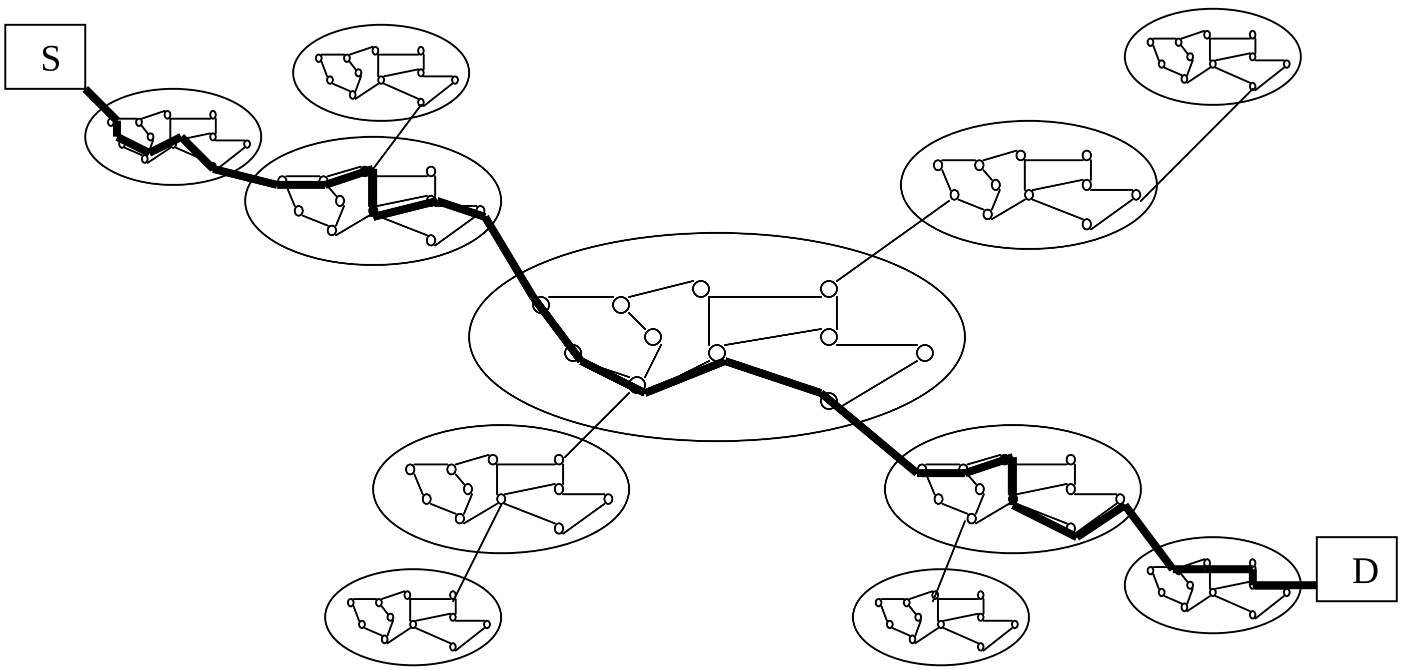
- **Security levels**
- **Current and new solutions**
- **Layered model for wireless networks**
- **Context Aware Management/Policy Manager (CAM/PM)**
- **Packet Level Authentication (PLA)**
- **Applications**
- **Performance**
- **Conclusions**

Internet

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



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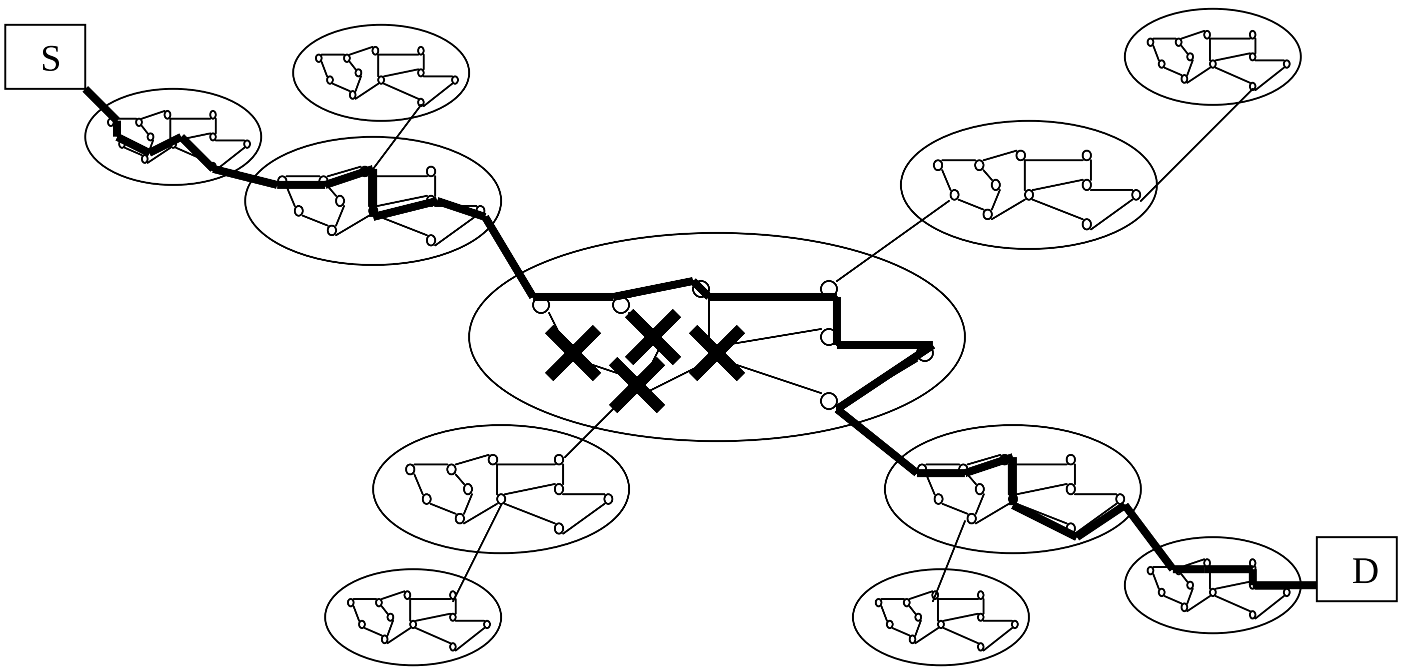
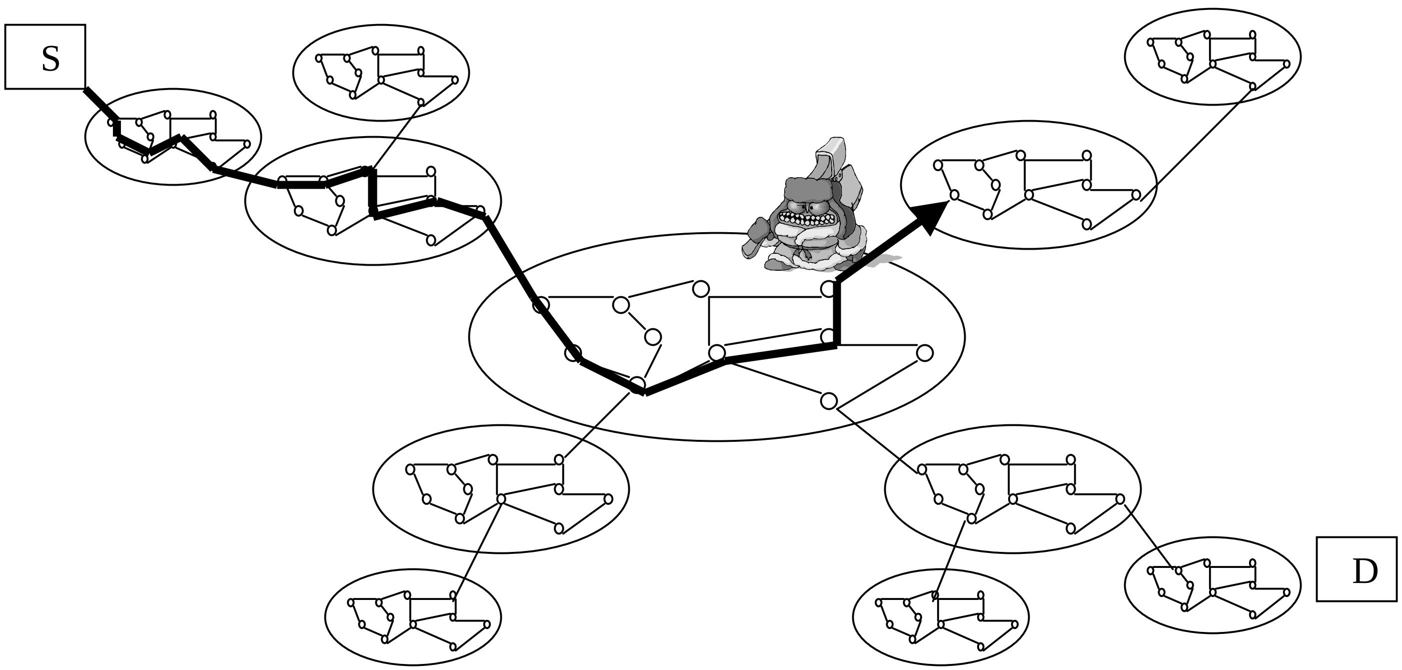
Internet

- **Packets can be rerouted quickly**



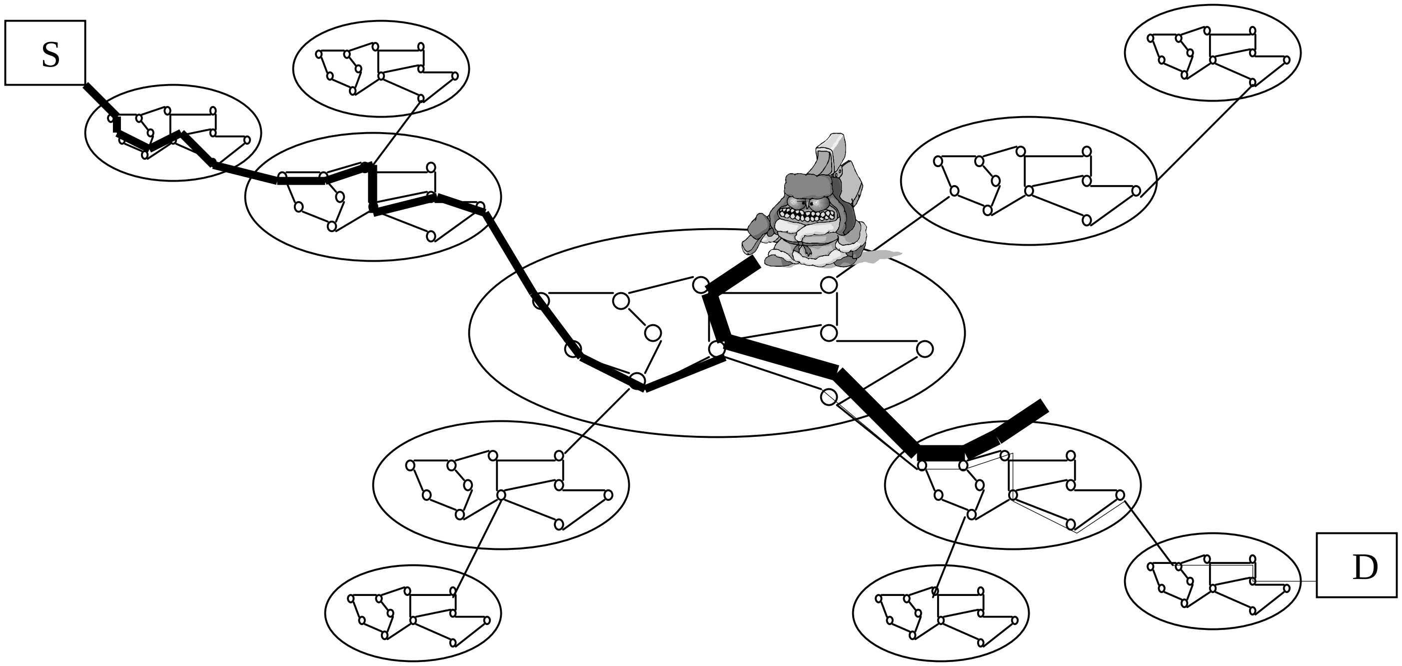
Internet

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



Internet

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



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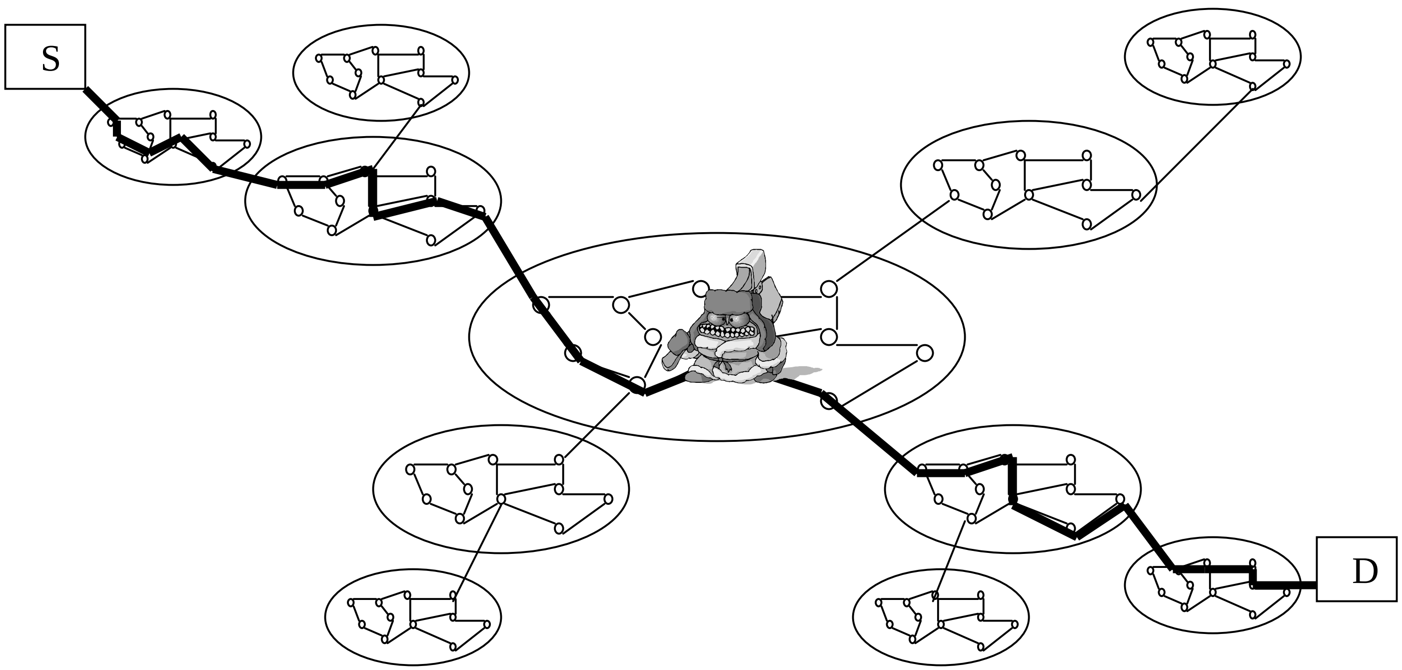
Internet

- **...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

5 categories of privacy

- Data privacy (content)
- Identity privacy (source/destination)
- Location privacy (place)
- Time privacy (when)
- Privacy of existence (does it exist)

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**
- **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 (reliable) communication**
  - **in military grade (hostile enemies, compromised nodes, high casualty rate)**
    - **wireless (eavesdropping, disturbance, unreliable links)**
      - **ad hoc networks (no static infrastructure, mobile nodes, dynamic routing)**

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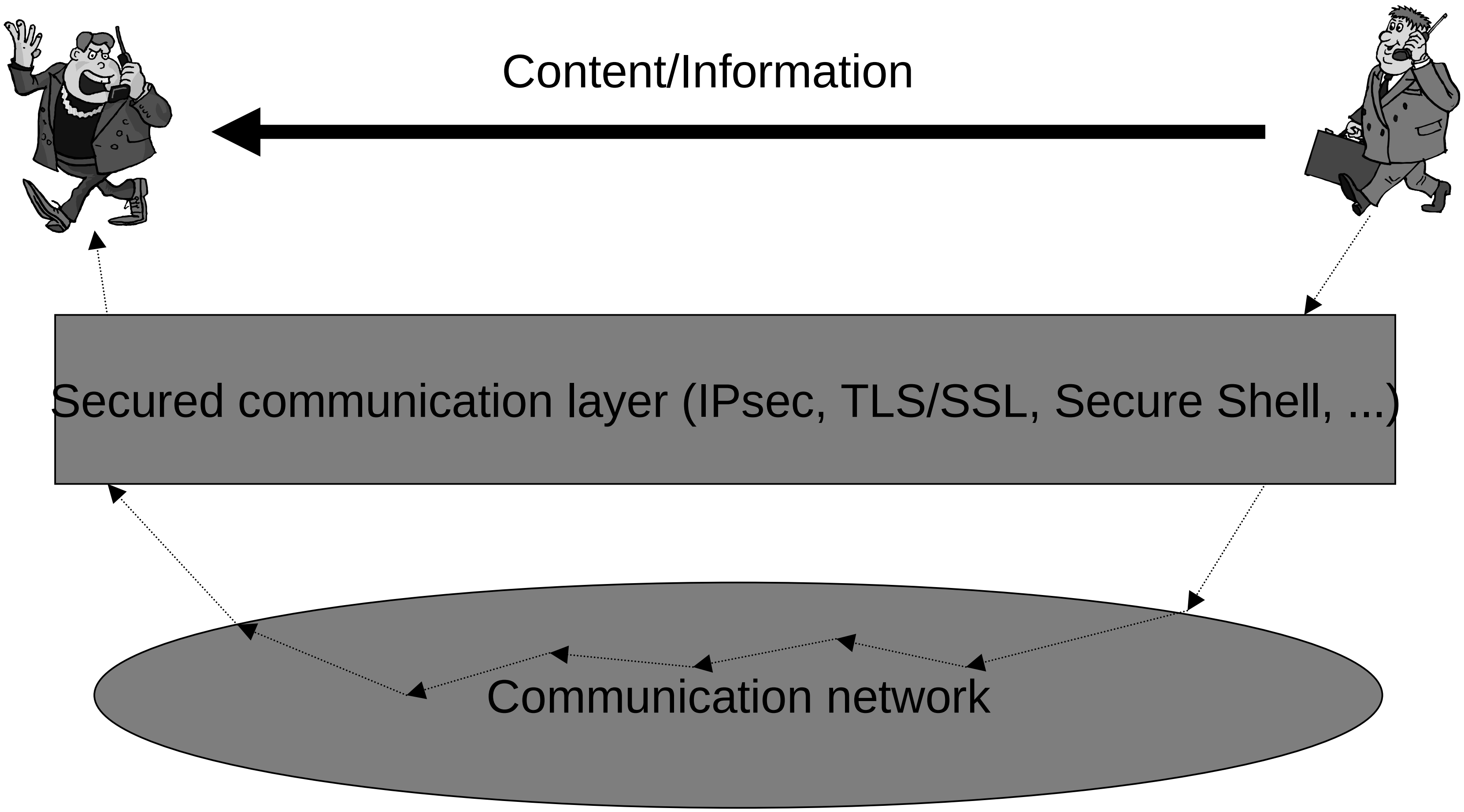
3 levels of security



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**

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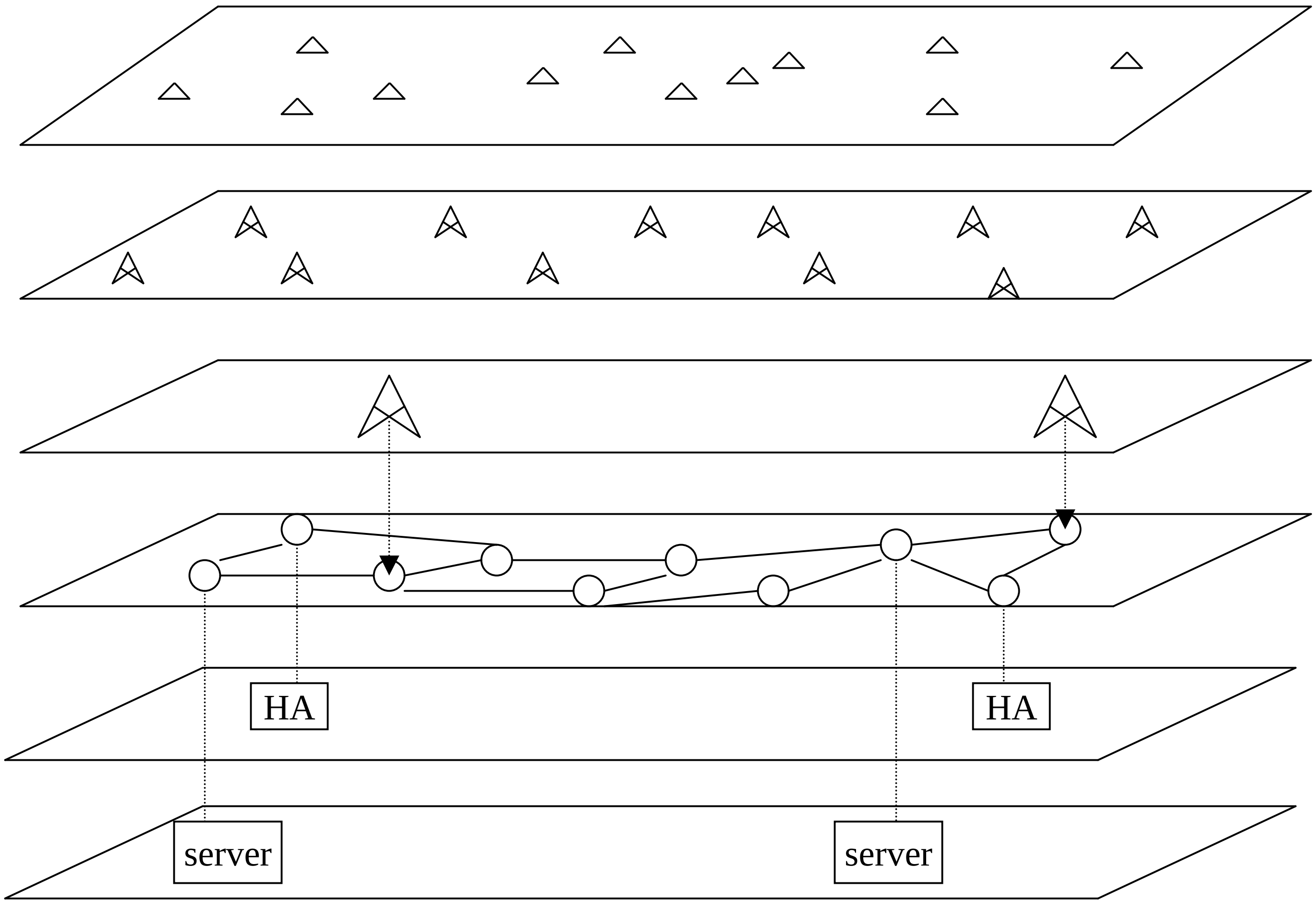
Layered model for wireless networks



mobile node level

ad hoc router level

access network level

core network level

mobility level

server level

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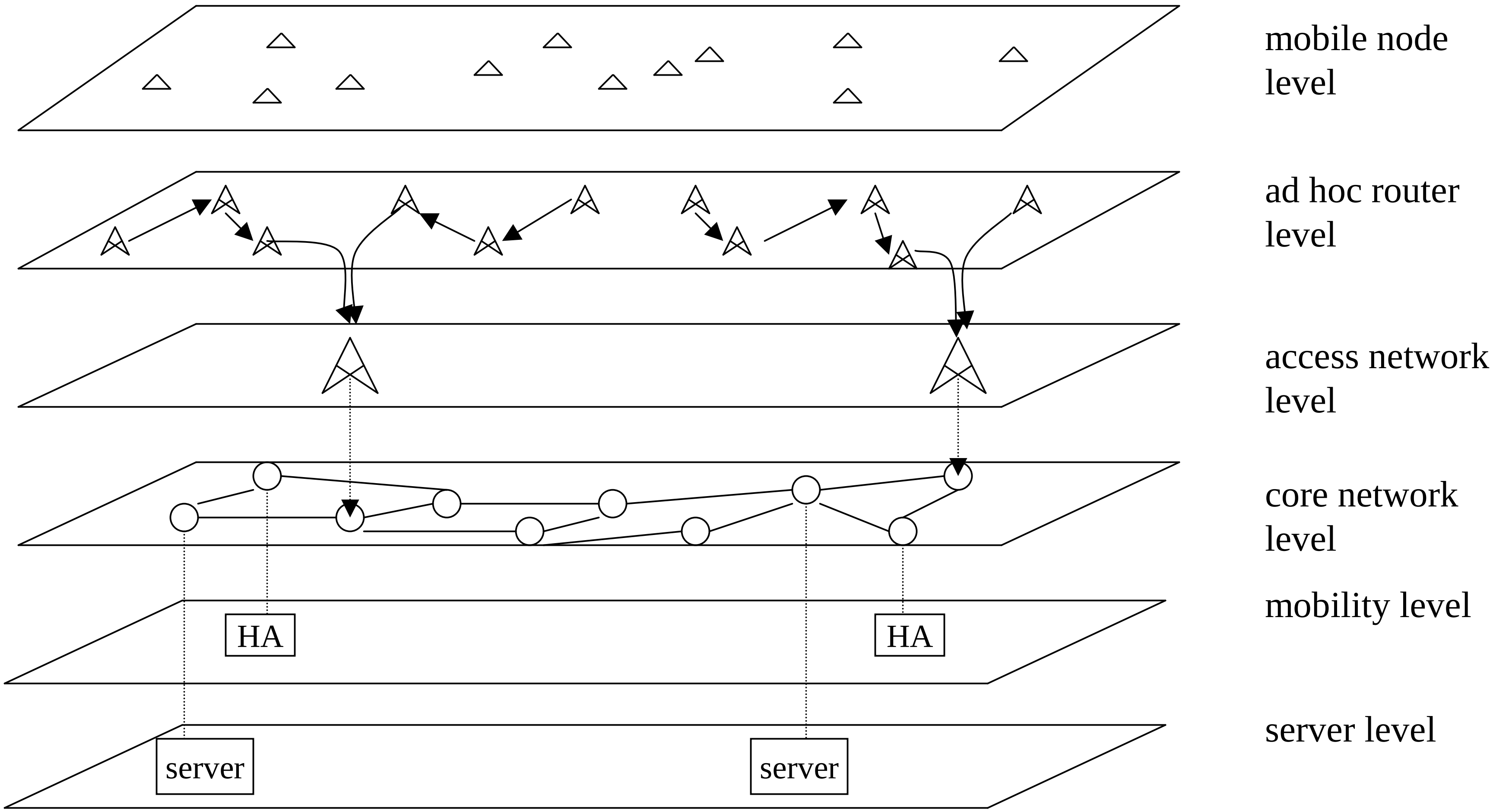
Layered model for wireless networks: ad hoc routers



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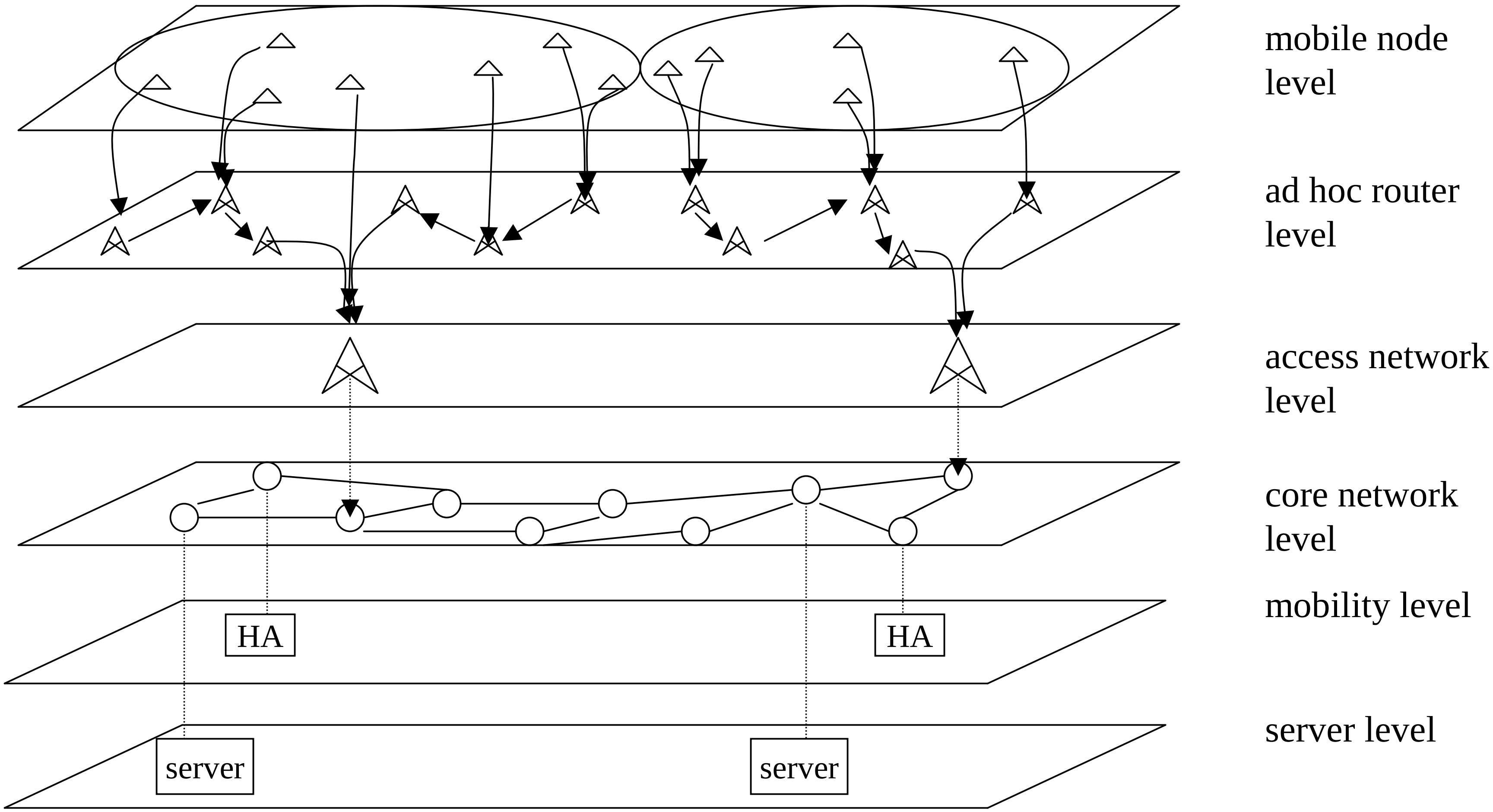
Layered model for wireless networks: mobile nodes



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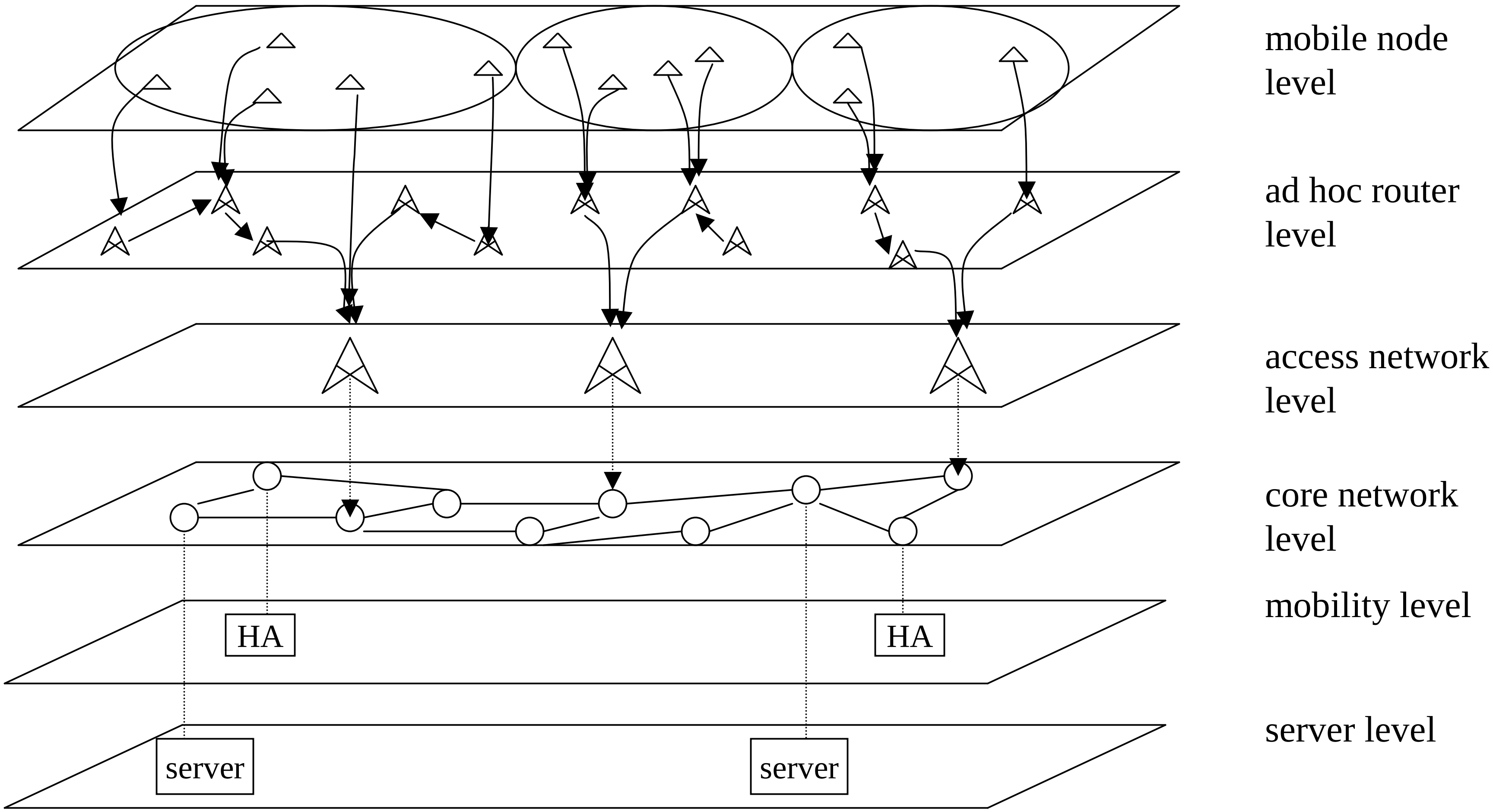
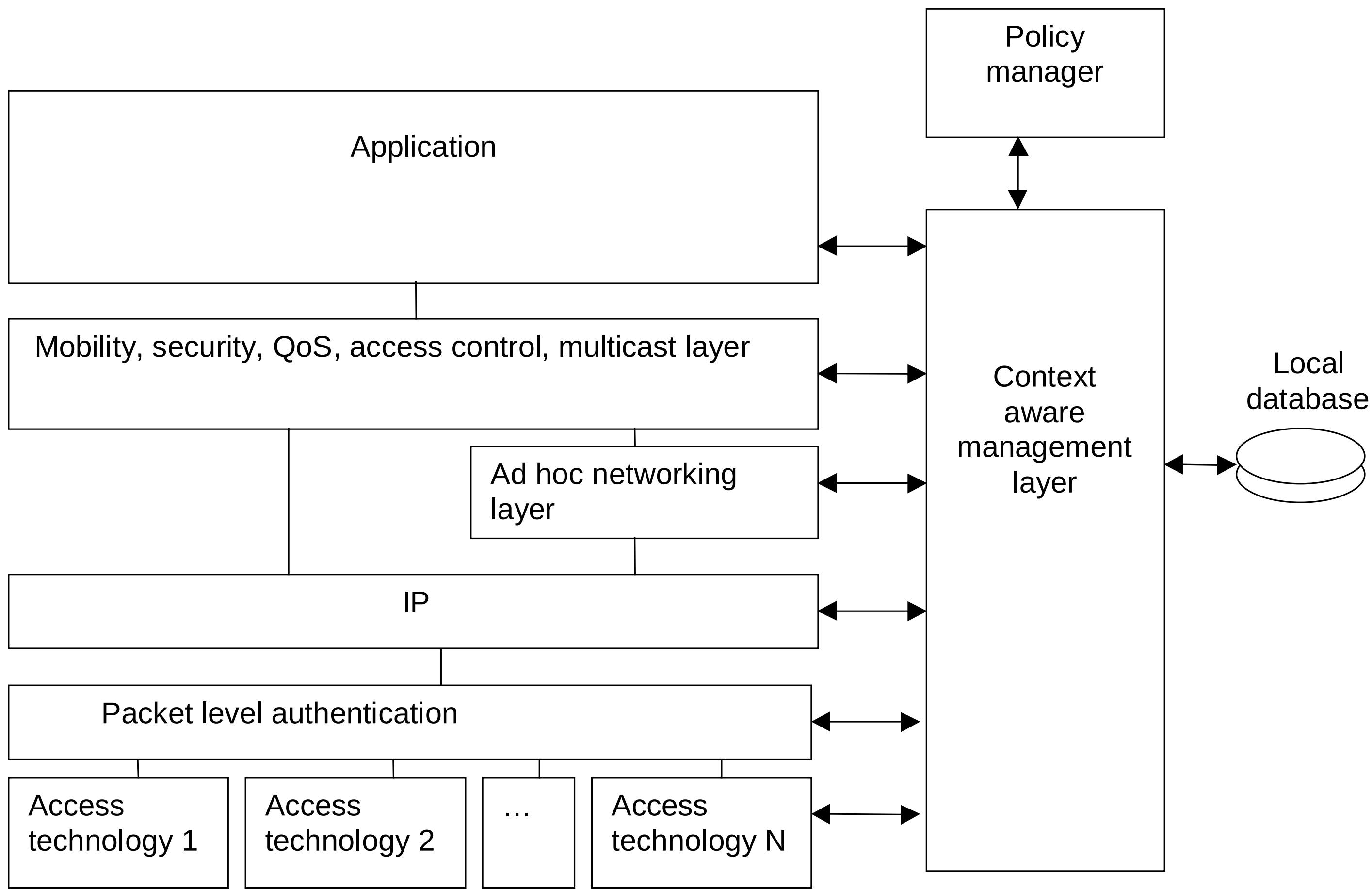
Layered model for wireless networks: new access point



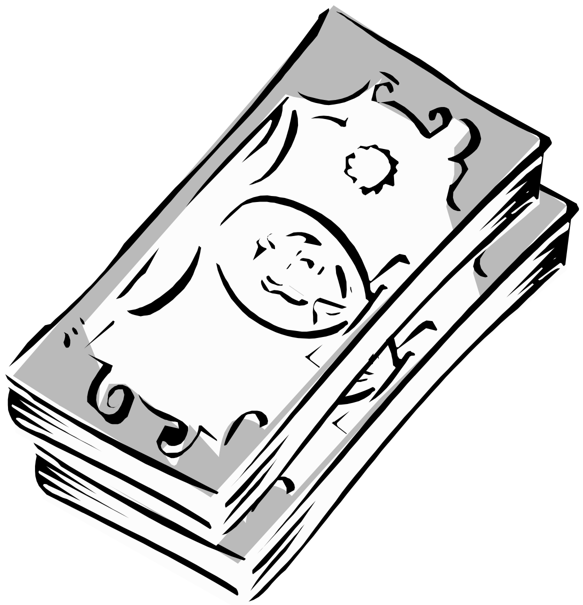
Context Aware Management/ Policy Manager



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)**

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**

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**

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**

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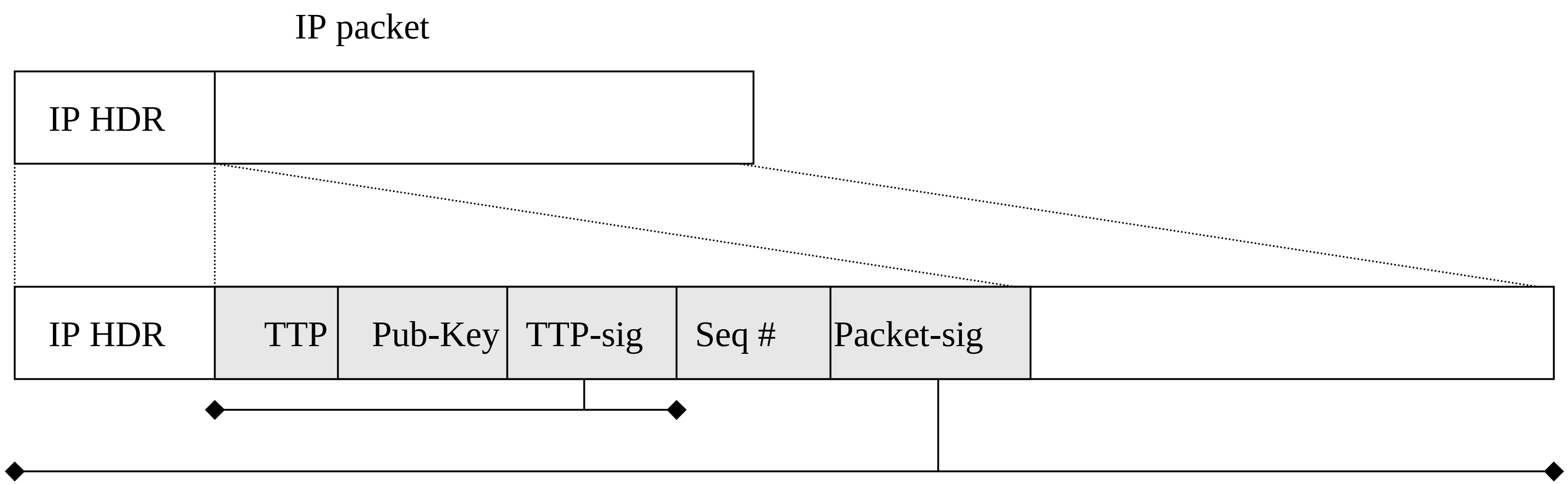
Packet level authentication: Implementation



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**

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**

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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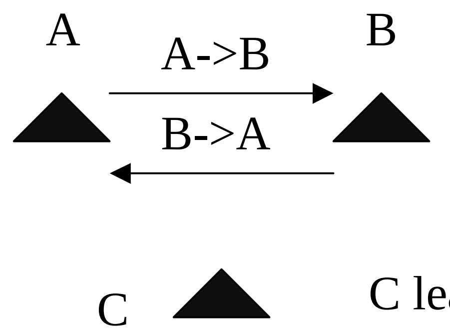
Applications for PLA

- **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**

Application: Quick secured communication in battle field

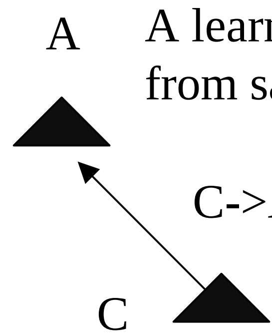
Any communication



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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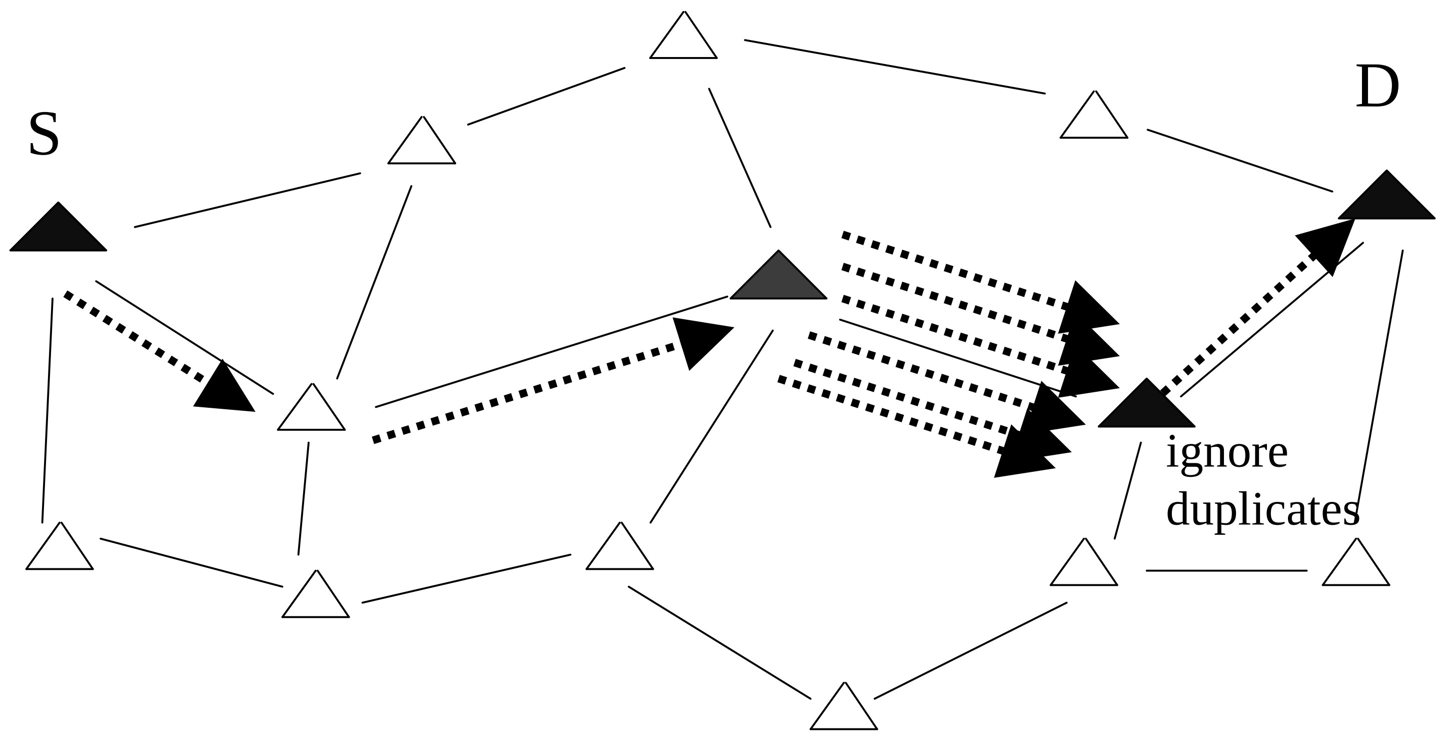
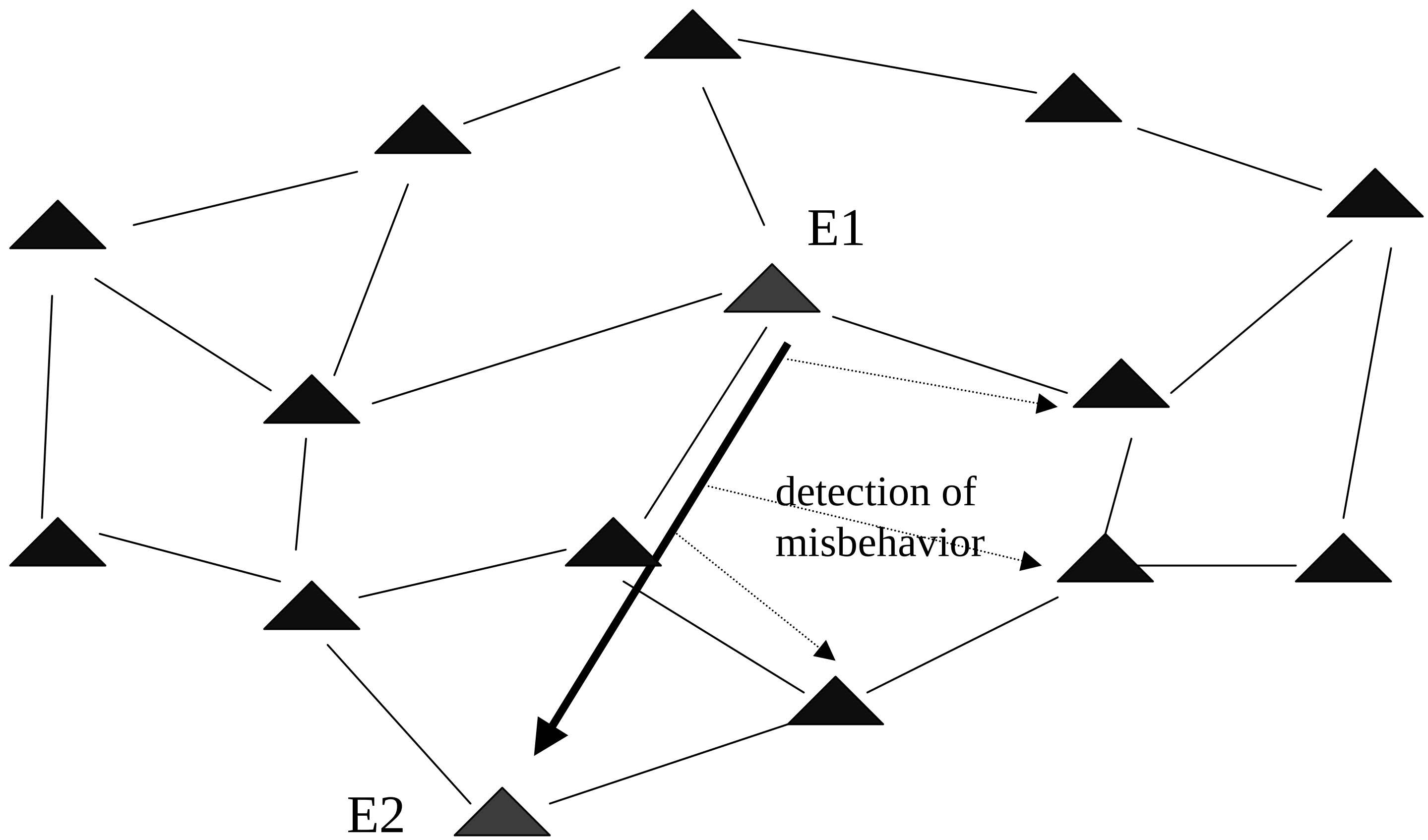
Application: Restricting DoS attack



Application:
Excluding compromised nodes



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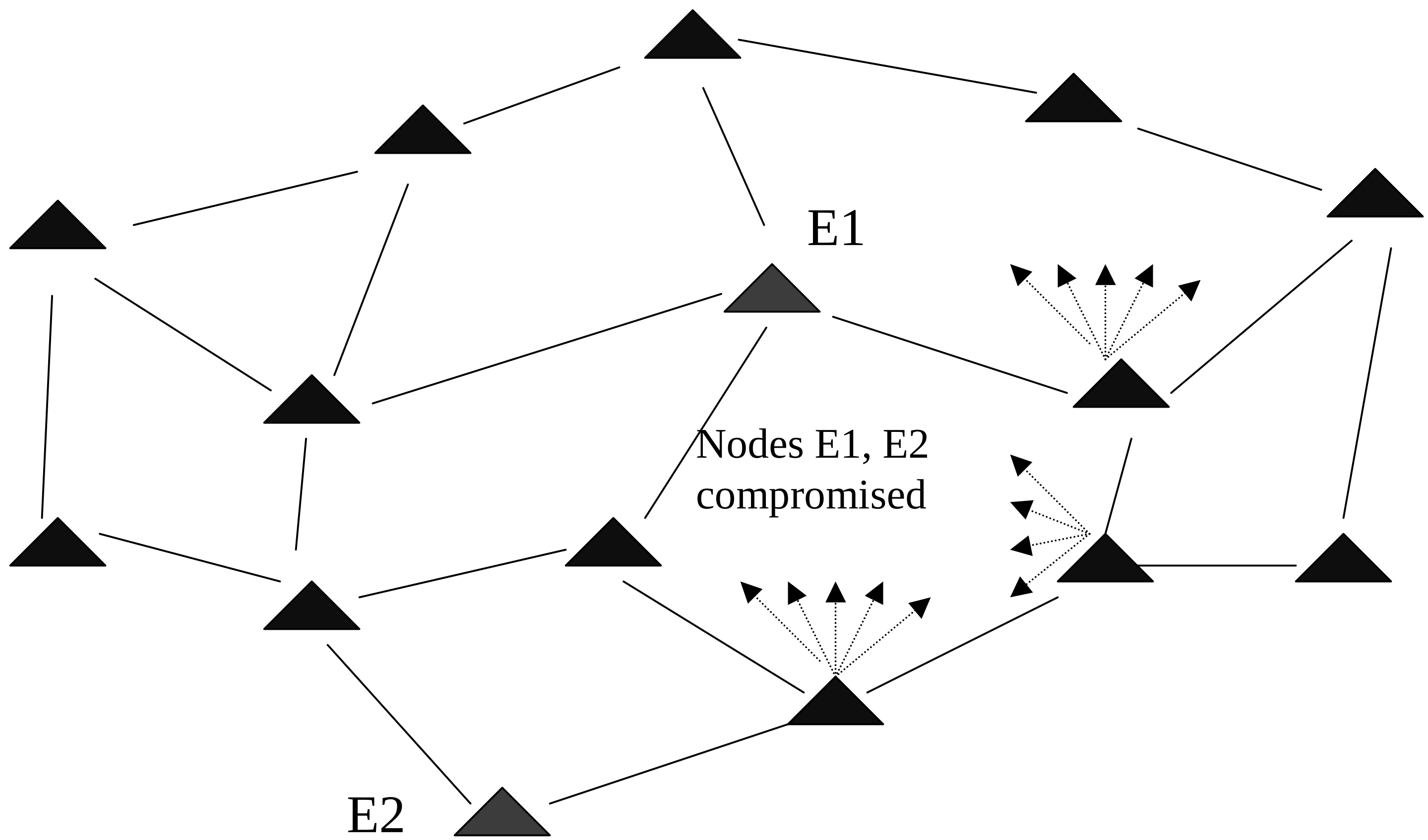
Application: Excluding compromised nodes



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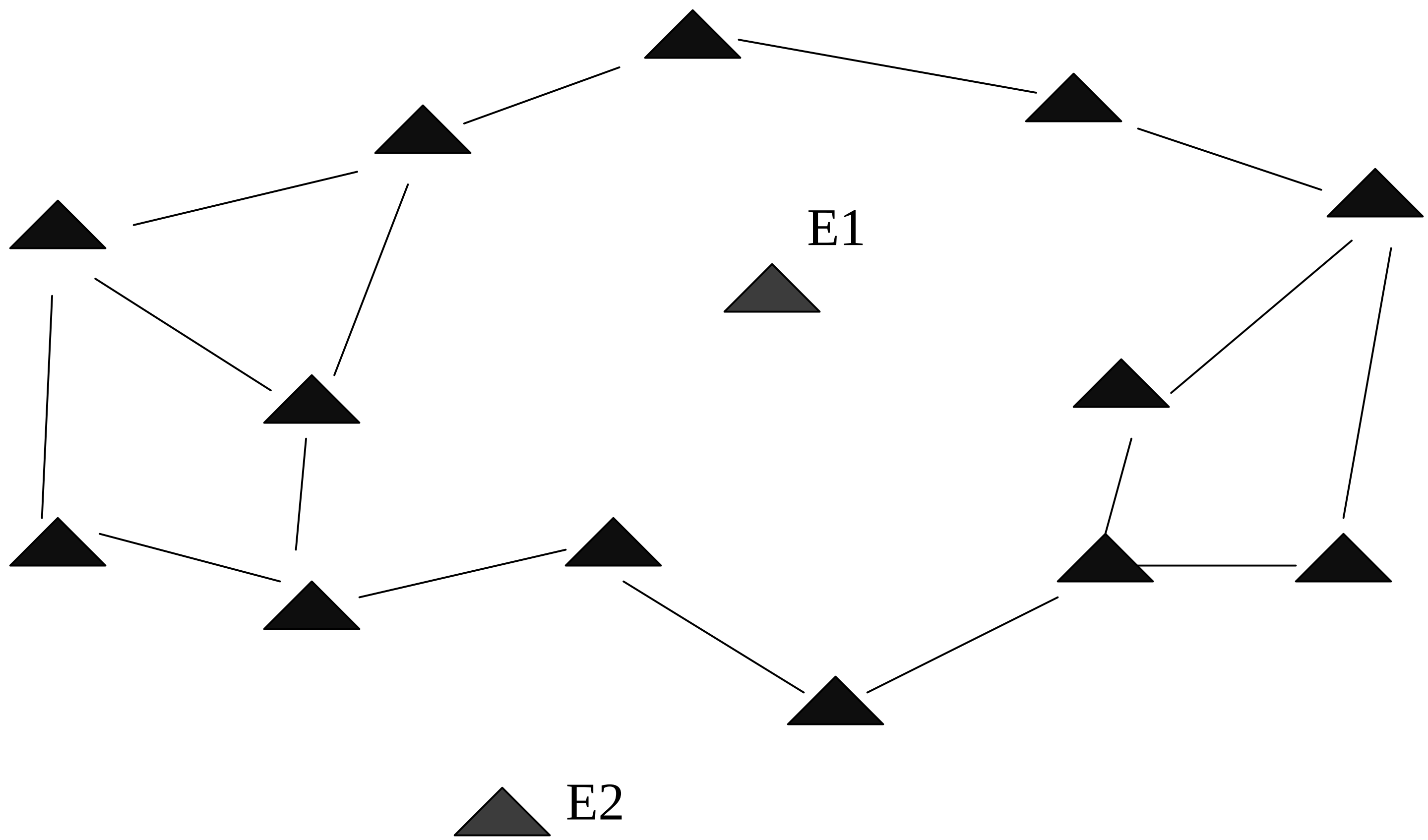
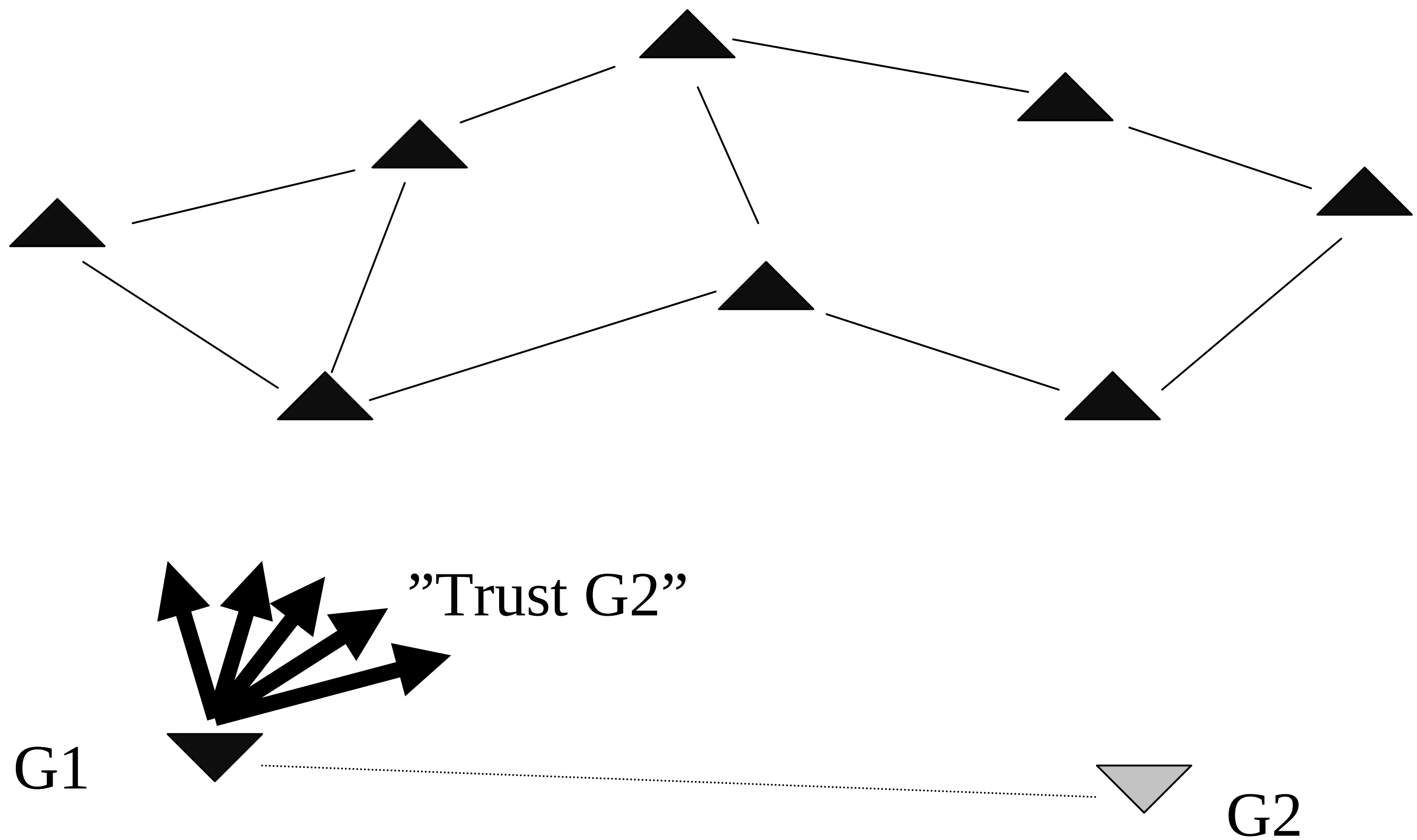
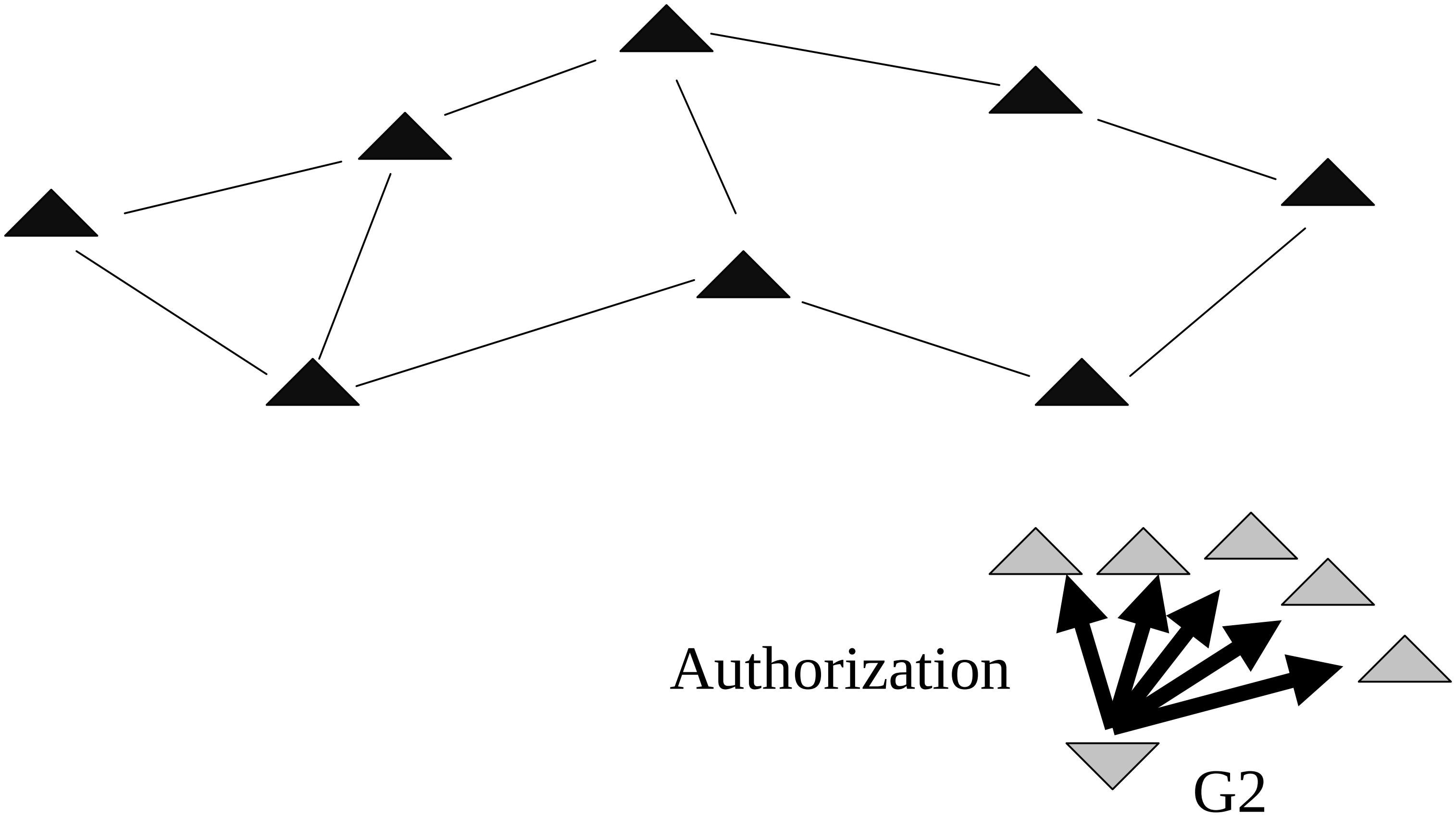
Application: Excluding compromised nodes



Application:
Delegation of command chain



Application:
Delegation of command chain



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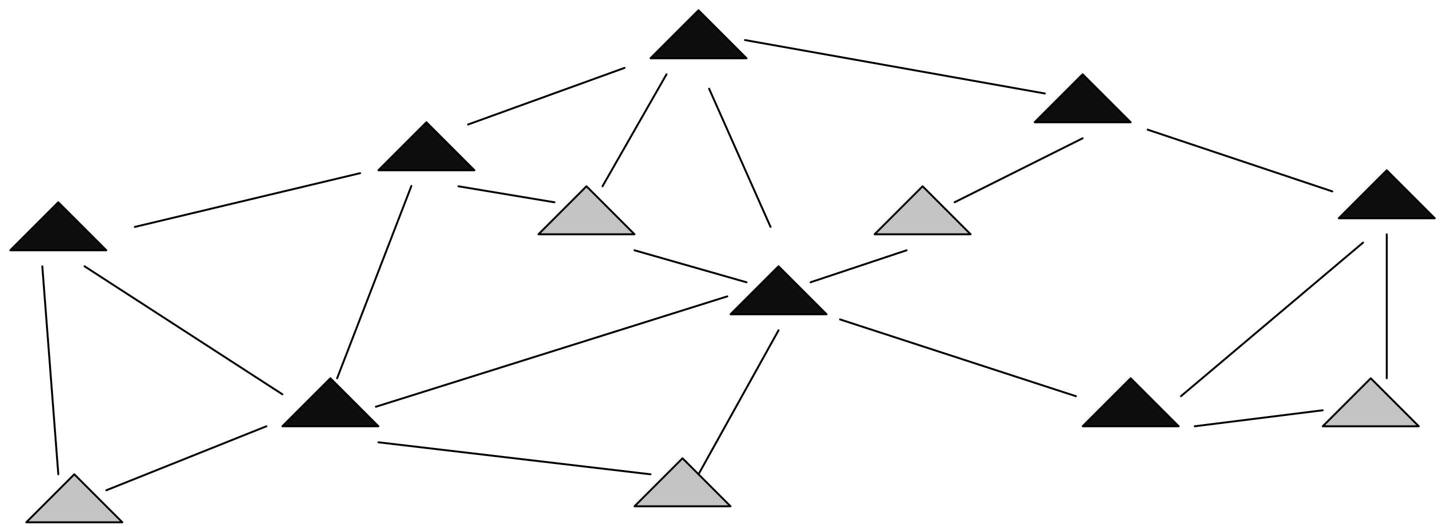
Application:
Delegation of command chain



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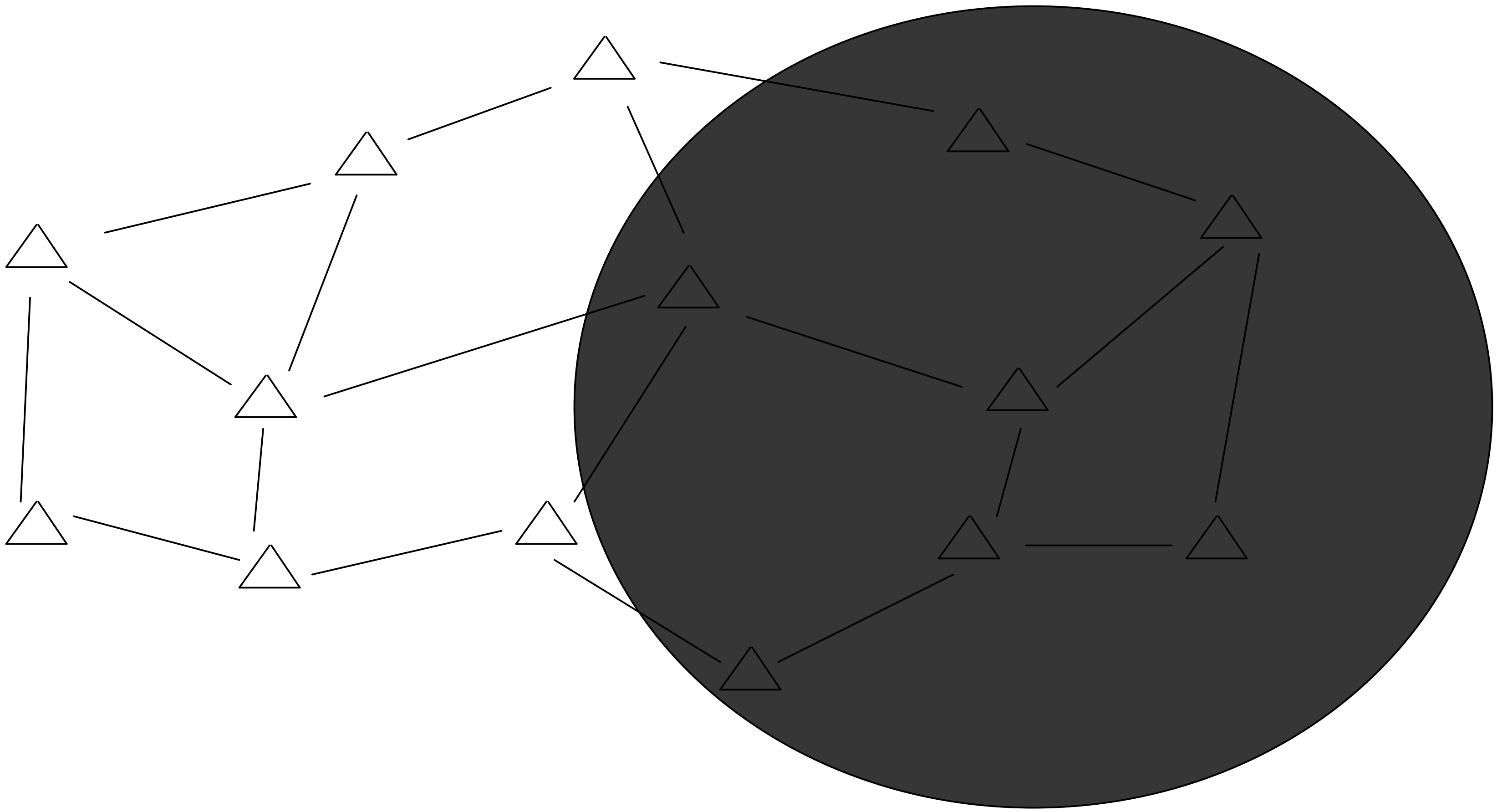
Application: Revocation of large quantity of nodes



Application: Revocation of large quantity of nodes

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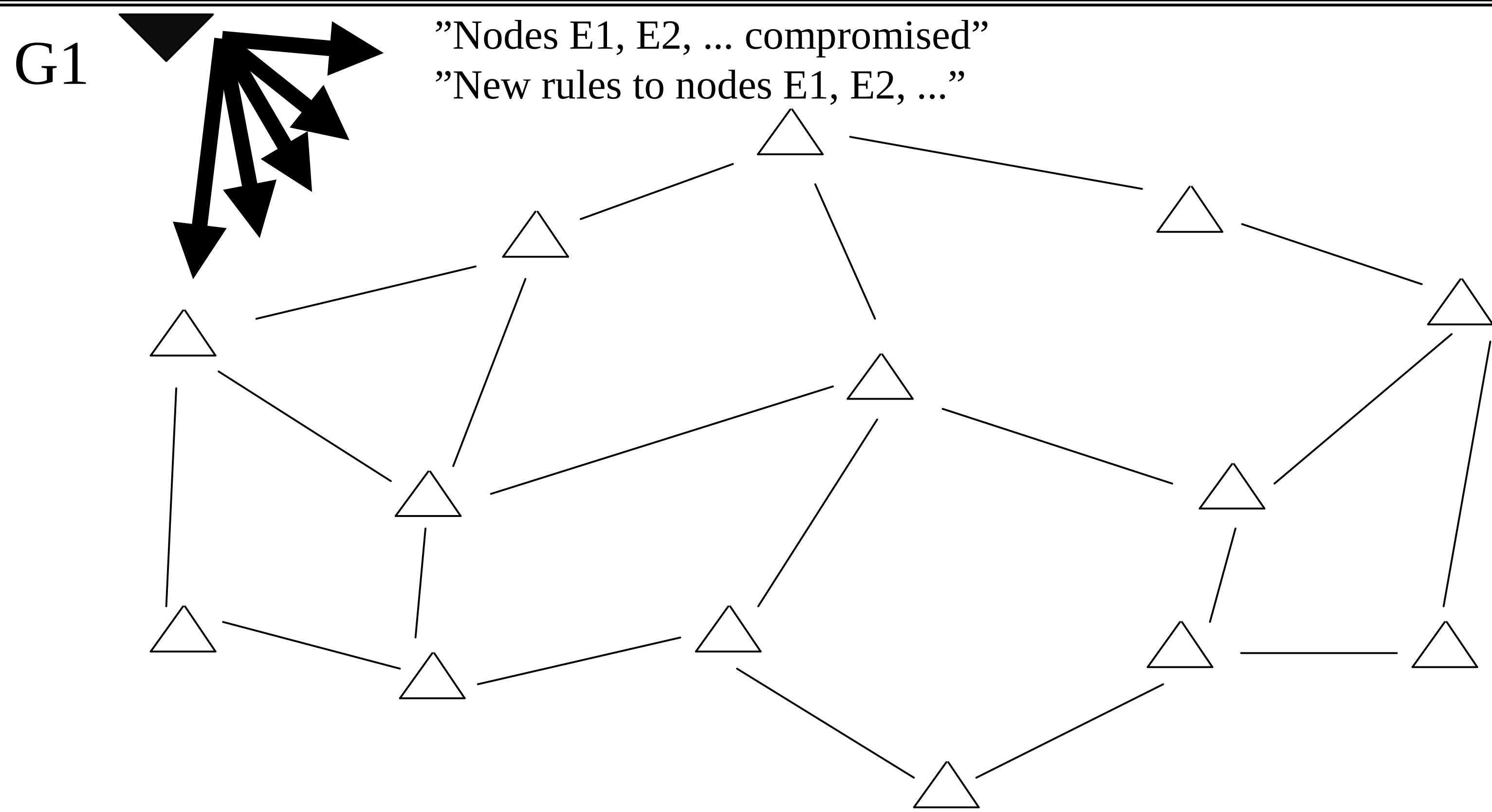

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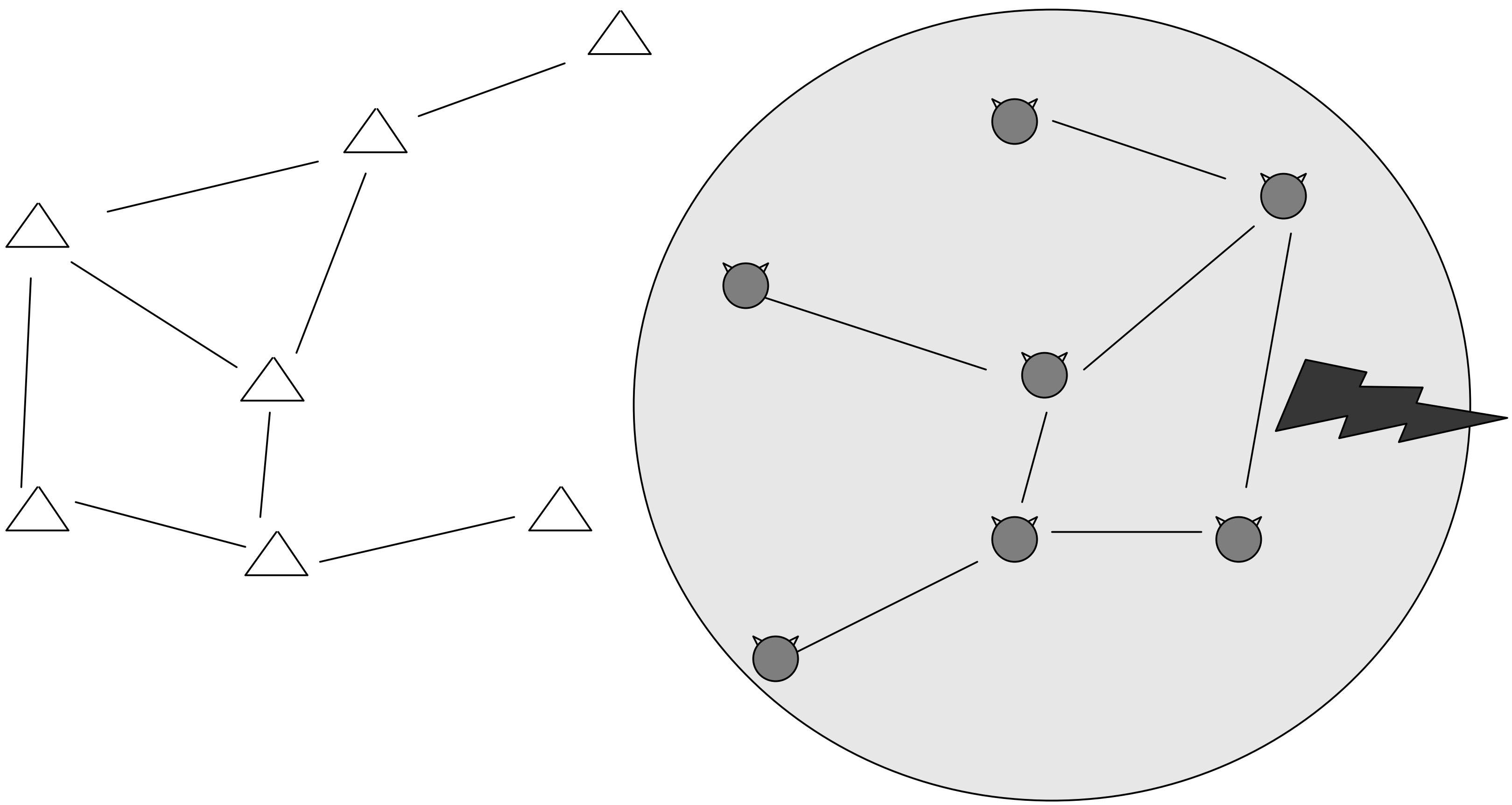
Application: Revocation of large quantity of nodes



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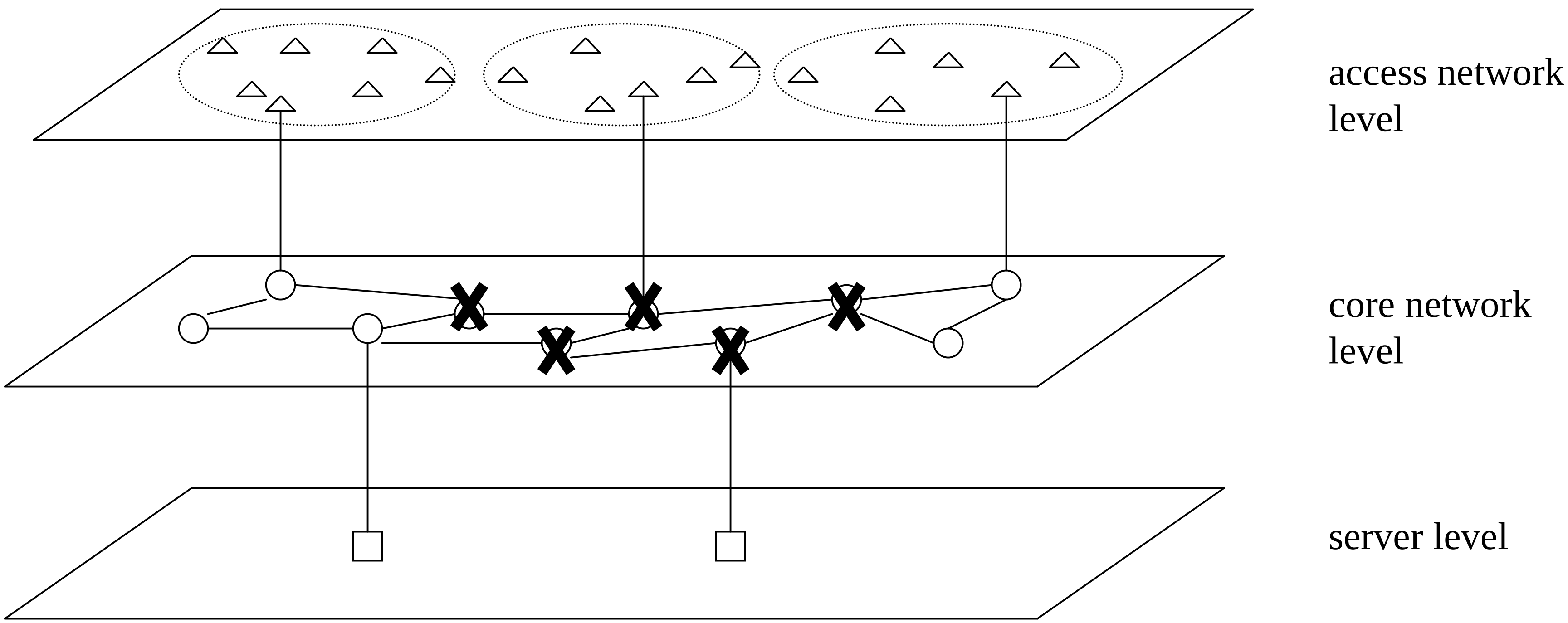
Application: New core network: Military strike



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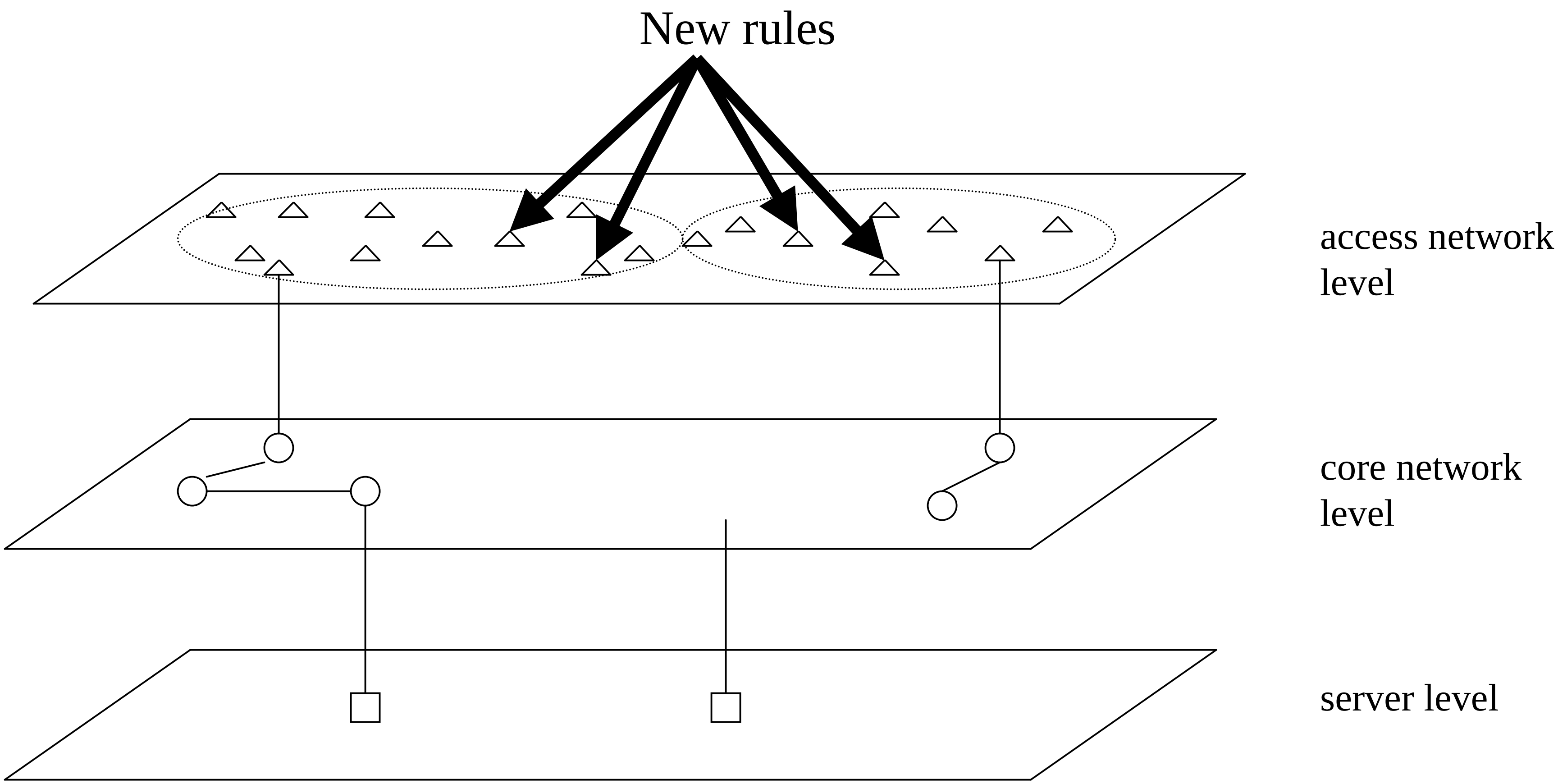
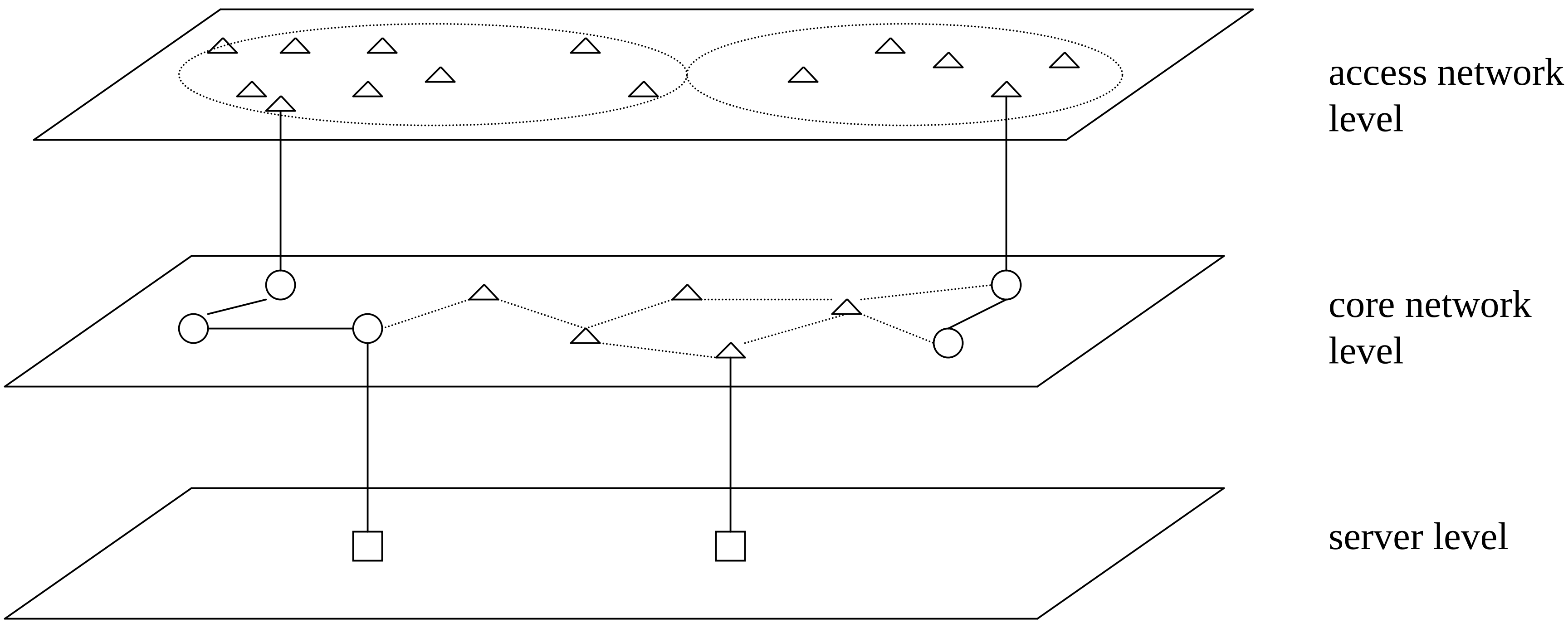
Application: New core network: Reconfiguration



Application: New core network: After military strike



Performance

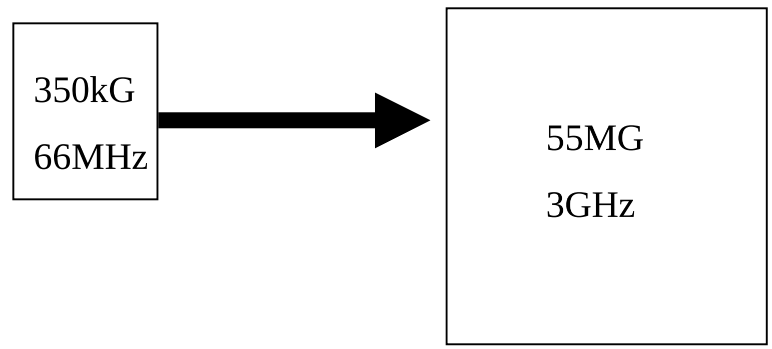
- **Sending node**
  - **One digital signature per packet**
- **Verifying node/Receiving node**
  - **First packet:**
    - **One certificate validation & One digital signature verification**
  - **Next packets:**
    - **One digital signature verification per packet**
- **Digital signature requires one hash and one elliptic curve operation**

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**

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)**



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

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

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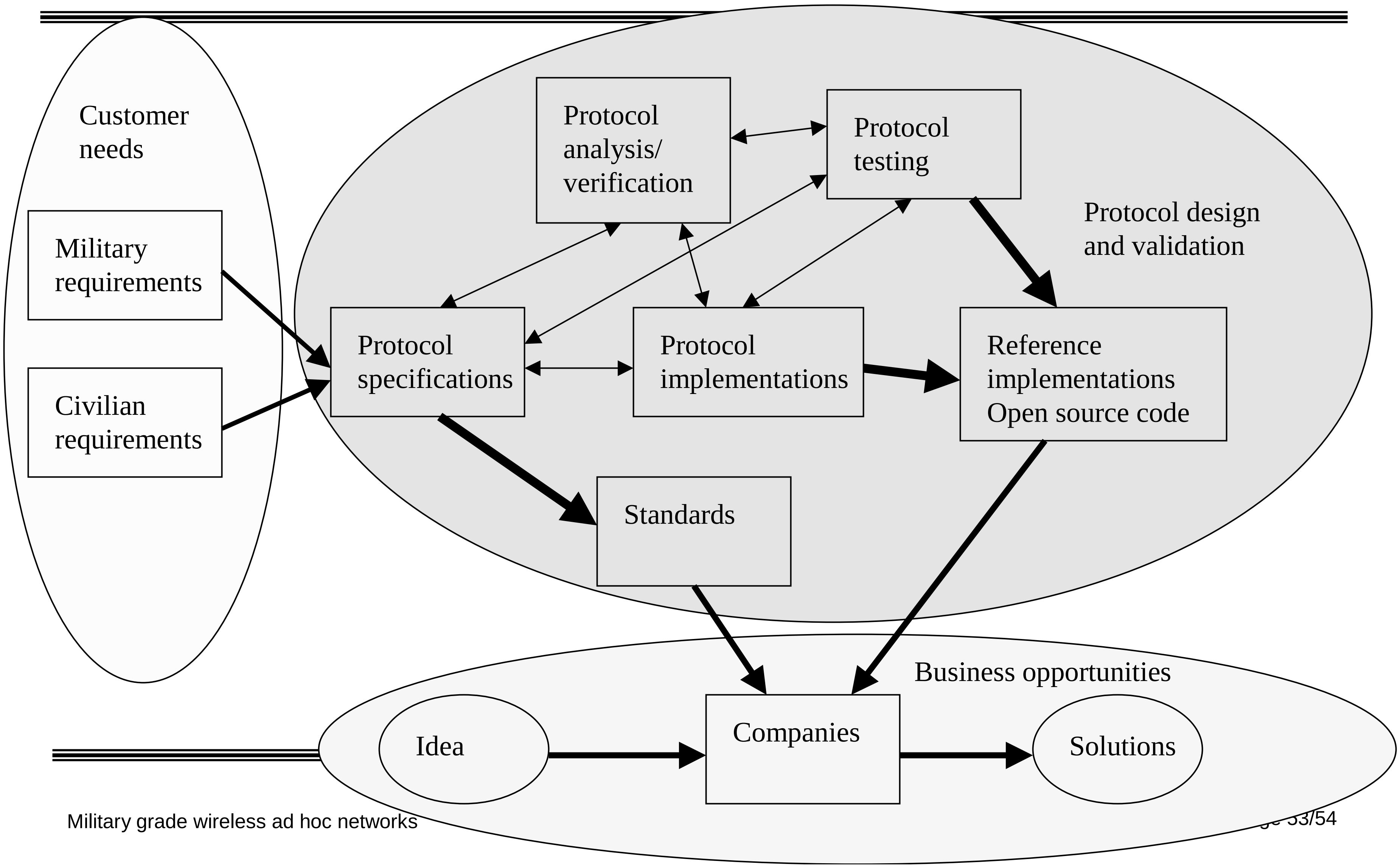
Operating model for open source research



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**