Adaptive Distributed Traffic Control Service for DDoS Attack Mitigation

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Joint work with

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The trouble with AN

Landmark technology leading to paradigm shift	Research / basic technology development	Entry into market
PCs	Intel 4004: 1971 Xerox Alto, 1972	IBM 5150 (PC): 1981
2-D Graphical User Interface	Xerox Alto, 1972	Apple Lisa, 1983
Ethernet	Xerox, 1970-73	Approximately 1980-83
TCP/IP	Internet: 1973	First commercial routers (Cisco Systems): 1986
UNIX	Edition 1: 1970	System IV: 1982 Sun Workstation with BSD: 1982
Active Networks	1969? 1982? 1993? 1996? 2004?	Not here yet!

What Went Wrong?

- Capsule model is scary, a security nightmare: Anybody can inject code into the network!
- Maintained equality (AN == Capsules) for too long
- Anything can be done statically, if of broad interest
- No killer application
- Did we eliminate the need for standardization?
- No real business case / business model

➢ Did not convince the industry
➢ Ran out of funding

➢ Challenge of promoting and introducing a disruptive technology was underestimated

Three Ways Out

a) Switch to research in life sciences
b) Reboot and do purely basic research on AN/mobile code
c) Consider non-disruptive approaches

➢ b) and c) can be followed in combination

Outline

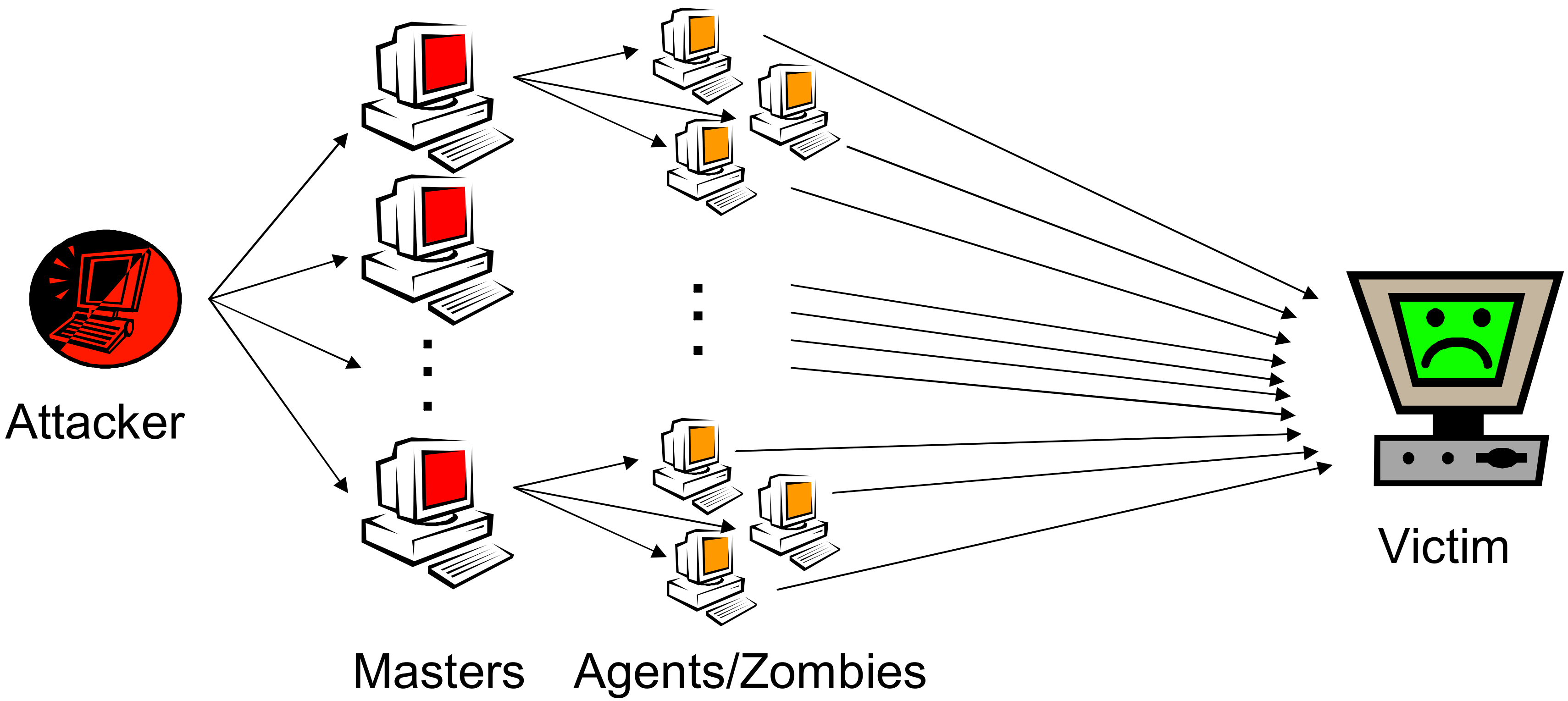
1. Introduction and problem statement
2. Approaches to denial of service mitigation
3. Distributed Traffic Control: Concepts and approach
4. Deployment Infrastructure
5. Conclusions

Introduction and problem statement

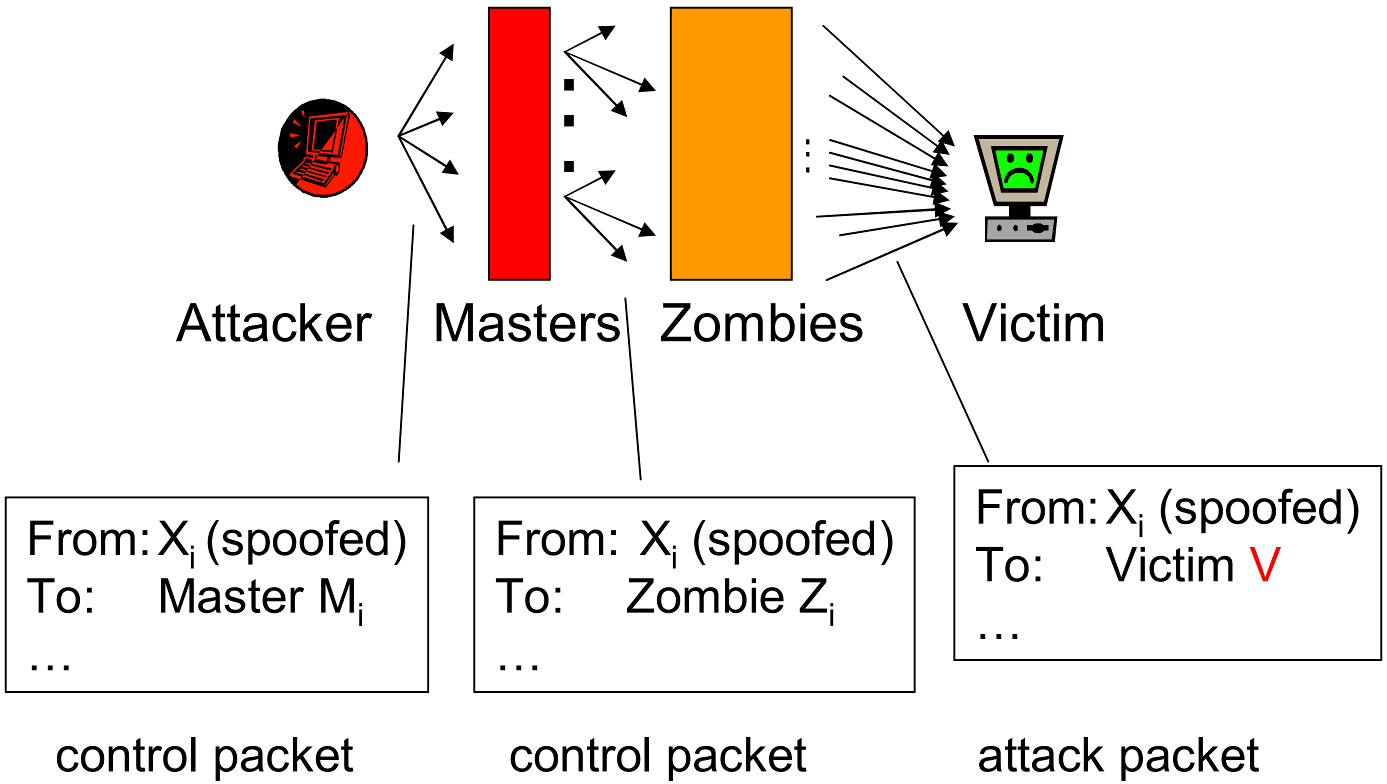
- Frequency of reported security incidents grows exponentially
  - 1988: 6 → 2003: 137‘529 [CERT]
- We will have to live with masses of ill-configured hosts
- Knowledge and tools for attackers abound
- Danger of massive attacks grows with the number of compromised hosts and the ease of mounting attacks
- Distributed denial of service (DDoS) attacks will be more frequent
- Defence focuses on hosts and company networks

➢ Need for security services *within* the network → a case for programmable networks!

Direct DDoS attack



Analysis of direct DDoS attack



From: X_i (spoofed)
To: Master M_i
…

control packet

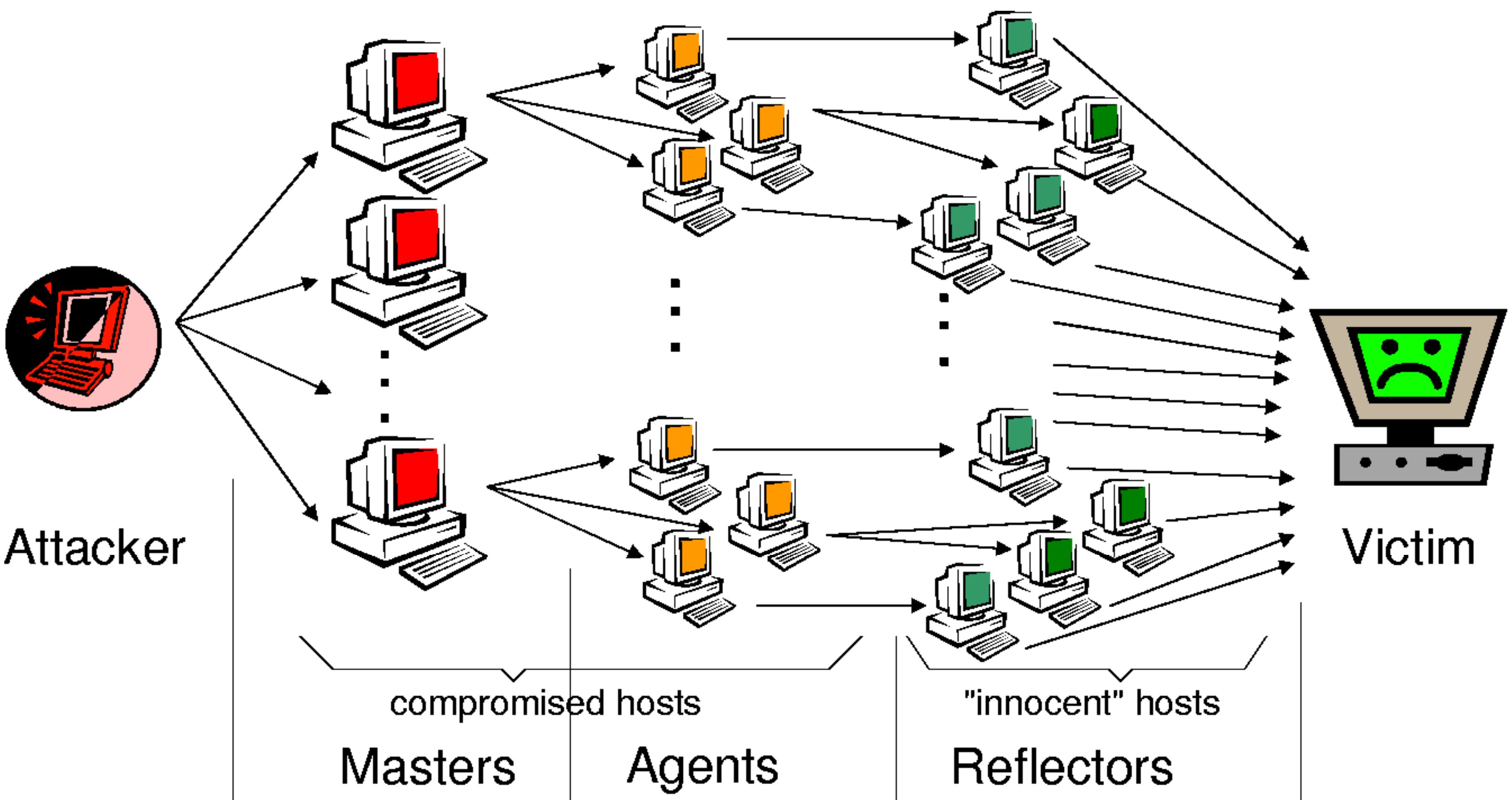
From: X_i (spoofed)
To: Zombie Z_i
…

control packet

From: X_i (spoofed)
To: Victim V
…

attack packet

Reflector DDoS attack



From: X_i (spoofed) To: Master M_i ...	From: X_i (spoofed) To: Zombie Z_i ...	From: **V(spoofed)** To: Reflector R_i ...	From: R_i To: Victim V ...
control packet	control packet	attack packet	legitimately looking attack packet

Role of amplification network

- Increase the rate of attack packets
  - Attacker sends a few control packets, victim gets it all
- Increase attack traffic by increasing packet size
  - If request packet size < reply packet size
- Increase the difficulty of counteraction
  - By making traceback difficult

Note:

- Attack traffic has V as a destination address (direct and reflector DDoS attack)
- Attack packet to reflector has V as the source address (reflector DDoS attack)

Approaches to denial of service mitigation

- Reactive approaches: Detect – identify - react – relax
  - Detection of DDoS attack
    - Sysadmin‘s experience
    - Traffic statistics (e.g. entropy of addresses, ports found in packets)
  - Identification
    - Source addresses are often spoofed
    - traceback to identify attack source
  - Reaction
    - Filter incoming attack traffic
    - Pushback (recursively follow congestion and rate-limit traffic)
    - Mount counter-attack
- Proactive approaches
  - Ingress filtering
  - Secure overlay networks, VPNs

Assessment of The State of The Art

Current mitigation schemes not effective enough:

- Detection is often difficult, due to differentiation between good and bad traffic
- Identification
  - Traceback may be useless, since it identifies zombies or reflectors
- Reaction
  - Filtering: what, where, and who?
  - Pushback may hit legitimate sources and needs ubiquitous deployment
  - Counter-attacks may hit the wrong targets
- Ingress filtering: quite simple, but not done (incentive?)
- Secure overlay networks, VPNs:
  - Scalability problems due to number of trust relations needed
  - Not adequate for generally accessible information services (Google, Yahoo, …)

Distributed Traffic Control: Concepts and Approach

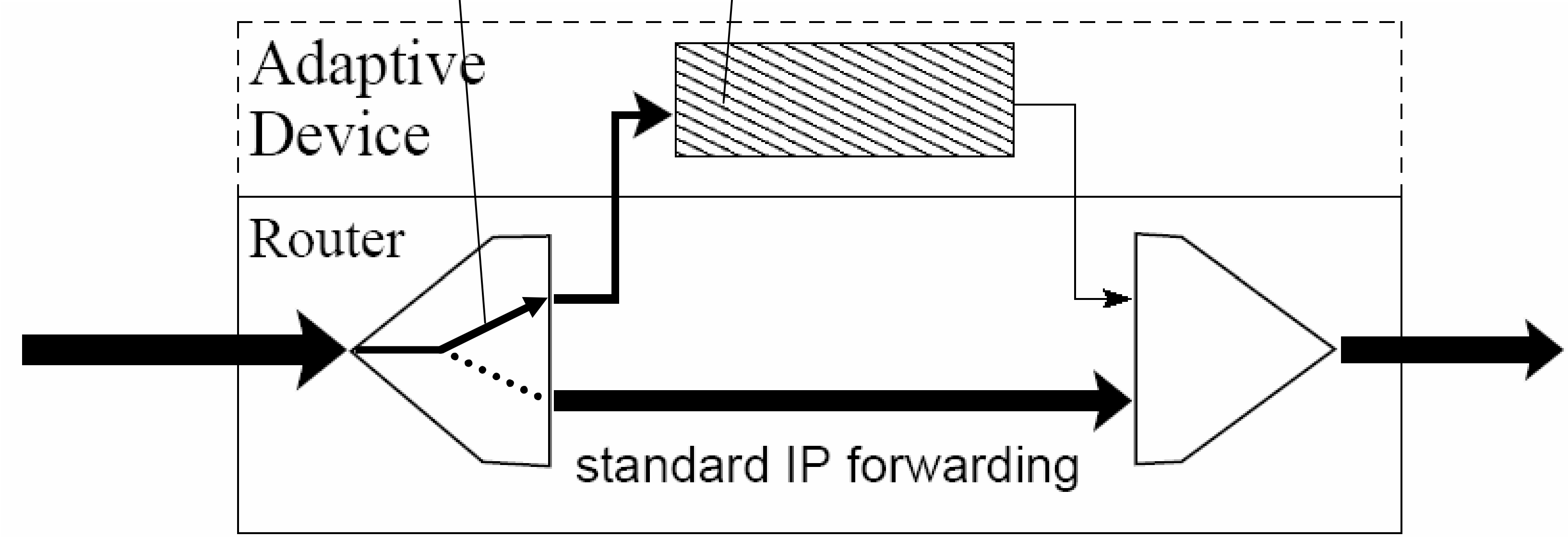
- What would you want to do as an operator of a service under attack?
  - 1a Direct DDoS attack: block packet coming towards you from certain ASes
  - 1b Reflector DDoS attack: block trigger packets flowing towards reflectors → „customer-specific“ ingress filtering
  - 2 Ask trustworthy ISPs/BSPs to install „suitable“ filters
- Suitable filters
  - – Act on packets that have your address as the source, destination or both
- Definition of traffic ownership
  - – Packet is „owned“ by network user who is officially registered to hold either the source or destination address or both

➢ You request ISPs/BSPs to take specific action on your (and only your!) packets

Traffic Control Device

This path only taken by user‘s own packets

User-programmable action
Virtualized per network user



Actions

- Restricted to prevent misuse
  - Acts only on packets owned by network user
  - No modification of source or destination addresses
  - No change of time to live (TTL)
  - No increase of packet rate and/or size
- Properties of user-defined functionality checked at installation or run time
- Context information available to user code
  - Allow for context-specific actions
Where am I? What type of traffic am I acting on?
  - Router state and configuration

➢ Prevention of collateral damage

➢ ISPs/BSPs don‘t lose control over their network

Actions for DDoS attack mitigation

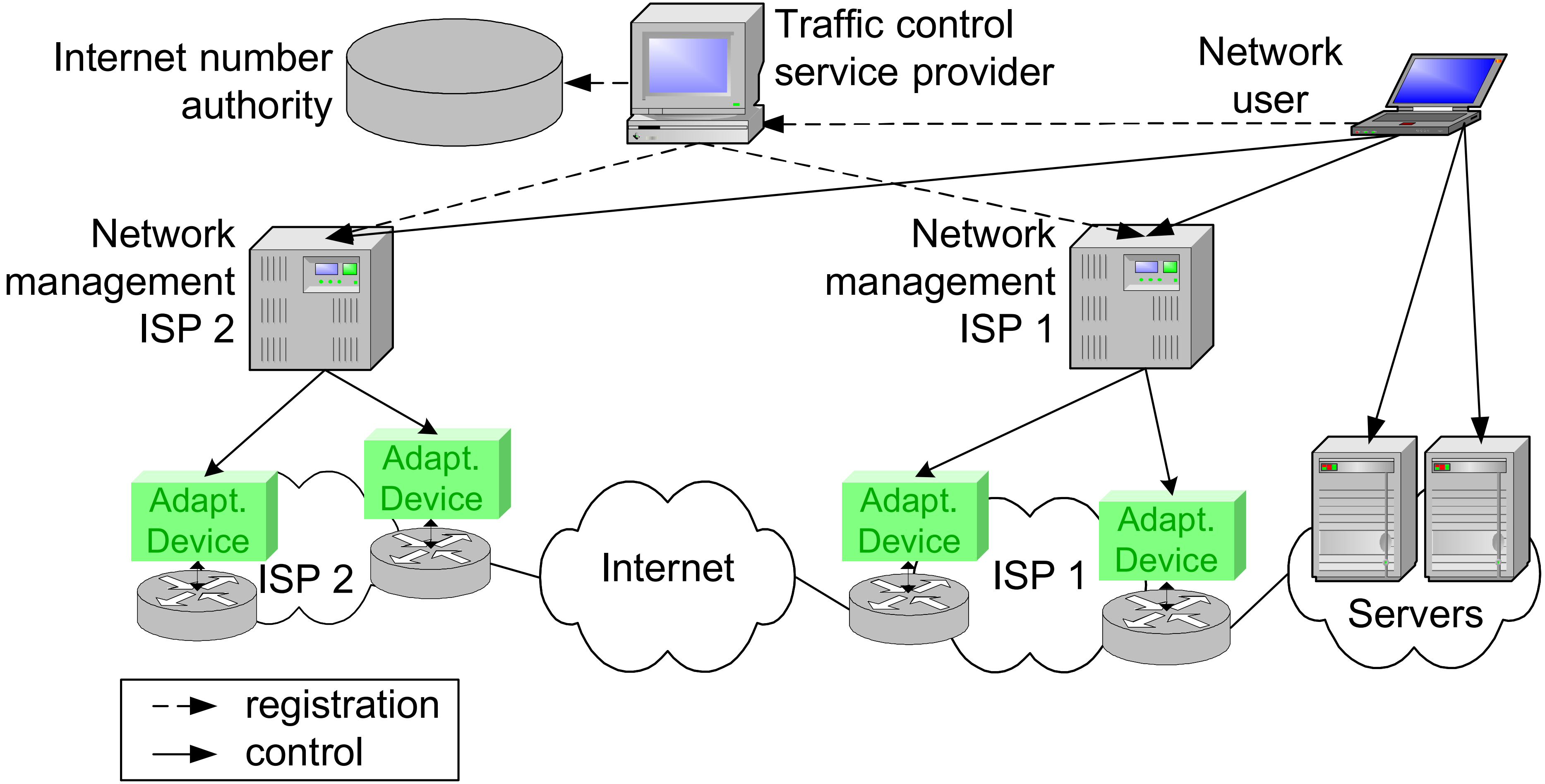
- Actions triggered by matching source/dest address, ports, payload, payload hashes
- Packet dropping
- Payload deletion
- Source blacklisting
- Traffic rate control

- ➢ User-specific ingress control
- ➢ Reactive or proactive
- ➢ Filtering close to source of attack traffic

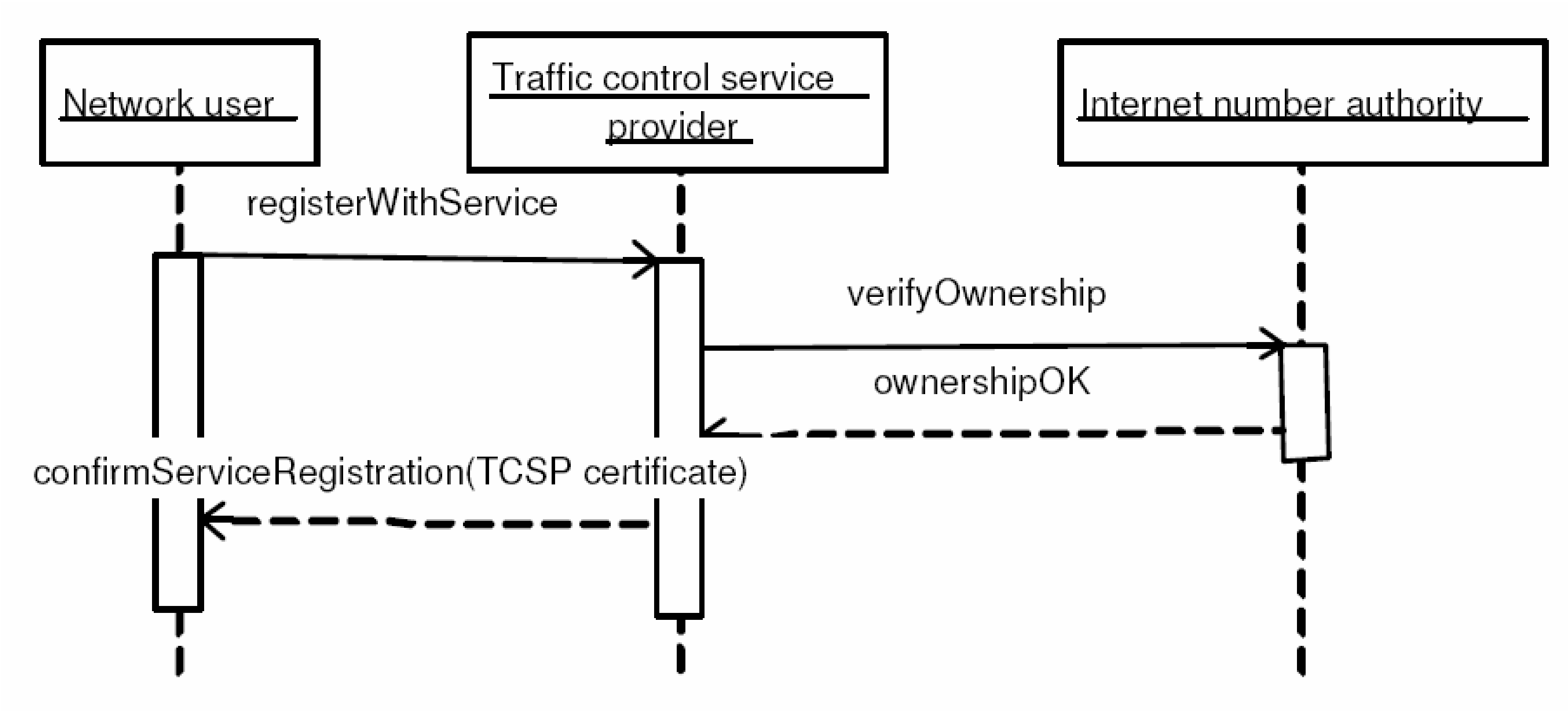
Other applications

- Traceback
  - Proactively collect packet hashes
  - Supporting network forensics
  - Locate origin of spoofed network traffic
- Automated reaction to traffic anomalies
  - Suspicious increase in connection attempts from/to server or network
  - Entropy variations in addresses and or ports
  - Detection of spoofing attempts
- Network debugging and optimization
  - Measure link delays, packet loss
  - Optimize content distribution network

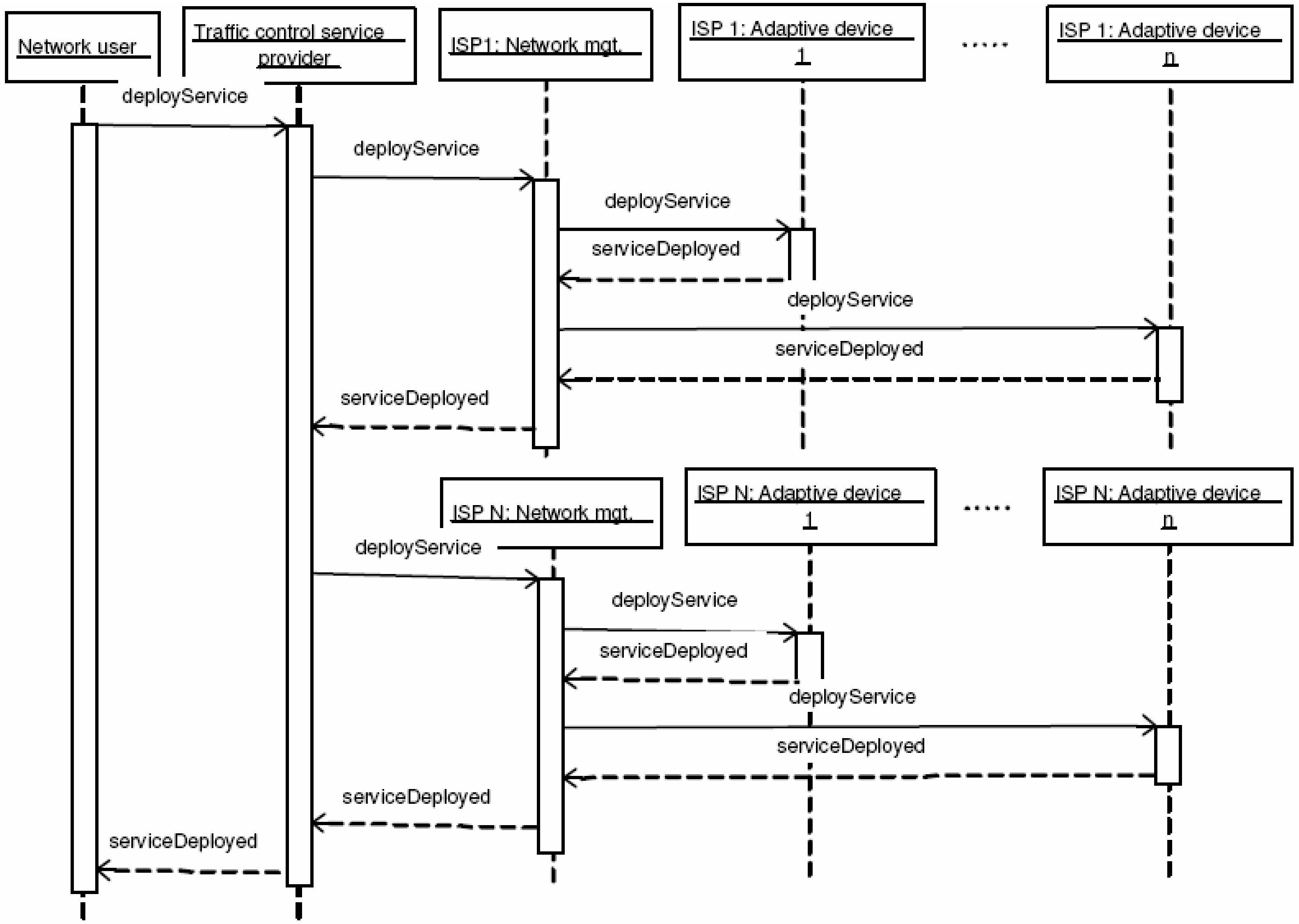
Deployment Infrastructure: Network Model



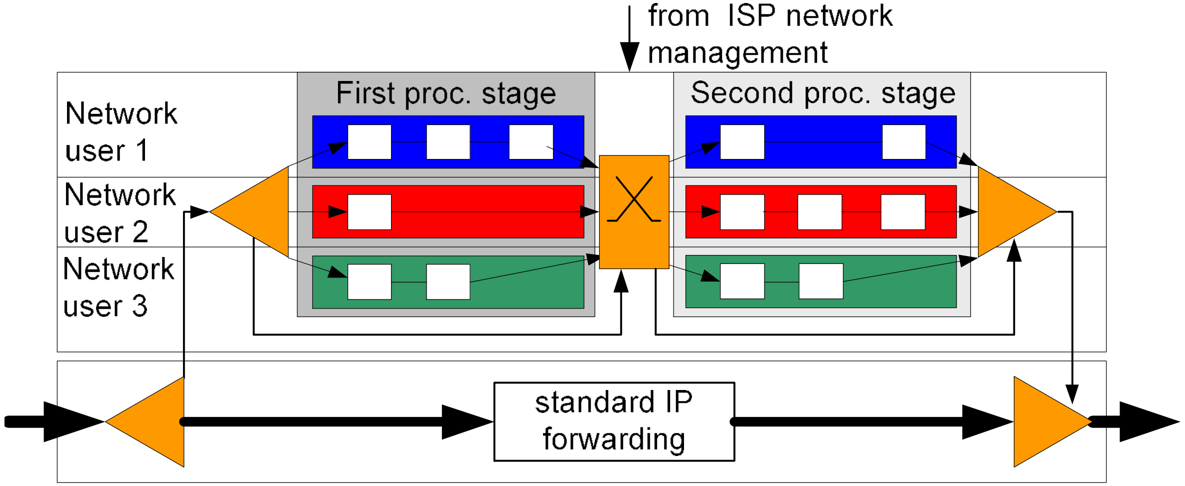
Service Registration


Network user
Traffic control service provider
Internet number authority
registerWithService
verifyOwnership
ownershipOK
confirmServiceRegistration(TCSP certificate)

Service Deployment



Node Architecture



- Premium service; few packets are rerouted through adaptive device
- Authenticated IP address owners can reprogram adaptive devices
- Filter order:
  1. Actions on behalf or owner of source IP address
  2. Actions on behalf or owner of destination IP address

Current status and future work

- International patent application filed (PCT/CH2004/000631)
- Proof of concept implementation underway
  - PromethOS environment
  - To be ported to Network Processor (Intel IXP line)
- Commercialisation
  - Box and service business
  - Start-up company
  - Patent licencing
  - Co-operation with interested company: Trade patent against research money.

➢ Example of „modest“ active networking. More to follow?

Conclusions

- Any chance of success?
  - Control remains with the network service providers
  - Incrementally deployable
    - Add-on box
    - Function may be integrated in future routers
    - Not necessary to have complete coverage on all routers
  - Premium (paid) service for large customers (not home users!)
  - Business incentive for network service providers
- Did we address the issues?
  - Approach not scary for ISPs: Safe, scalable, controllable
  - Ever changing shape of DDoS threat needs adaptive solution
  - Standardization may happen through market forces
  - We have a business model and business proposition
  - Technology is *not* disruptive

Thank you!

Questions?