Berlin Institute of Technology
FG Security in Telecommunications

Taming Mr Hayes: Mitigating Signaling Based Attacks on Smartphones

Dependable Systems and Networks (DSN) 2012

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OOKOUT BLOG

: Security Alert: DroidDream Malware

in Official Android Market

SECT

Attacks against smartphones
Attacks against cellular network infrastructure

Attacks against Smartphones

- Malware: trojans & botnets
  - Premium SMS fraud (this is common today!)
  - Data theft
  - Denial-of-Service … phone stops working

- Targets
  - End user
  - The actual smartphone

Rooted & Jailbroken Smartphones

- **Disable major security features of smartphone OS**

- User driven (voluntarily)
  - Gain full control over phone – access all “features”
  - Install “unauthorized” applications

- Rooting malware
  - Gain system privileges to access users data etc..
  - Abuse known root exploits
    (observed in the wild, e.g. DroidDream)

Attacks against Cellular Network Infrastructure

- Denial-of-Service attacks – reliability is their business!
  - Extortion
  - Cyber warfare

- Targets
  - Mobile Network Operators (MNOs)
  - Cellular infrastructure components

Previous Work tried to protect the Phone!

We aim to protect the network!

Signaling Attacks

- **Denial-of-Service (DoS) attack against cellular network**

- Targets: cellular infrastructure components
  - Home Location Register (HLR)
  - Packet-Data Infrastructure
  - ...

- Attacks executed by hijacked smartphones
  - Malware: trojans and botnets

- Accidental misuse or misconfiguration by the user

`GSMA Network Efficiency Threats v0.4, May 2010`

Prevent Signaling Attacks

- **Cellular network side**
  - Very expensive
  - Slow adoption

- **Cellular modem “baseband” side**
  - No access to sources
  - Modification → re-certification (slow)

Prevent Signaling Attacks

- **Cellular network side**
  - Very expensive
  - Slow adoption
- **Cellular modem “baseband” side**
  - No access to sources
  - Modification → re-certification (slow)
- Our solution: **Smartphone side**
  - New smartphone released every 6 month
  - Fast adoption possible!

Contributions

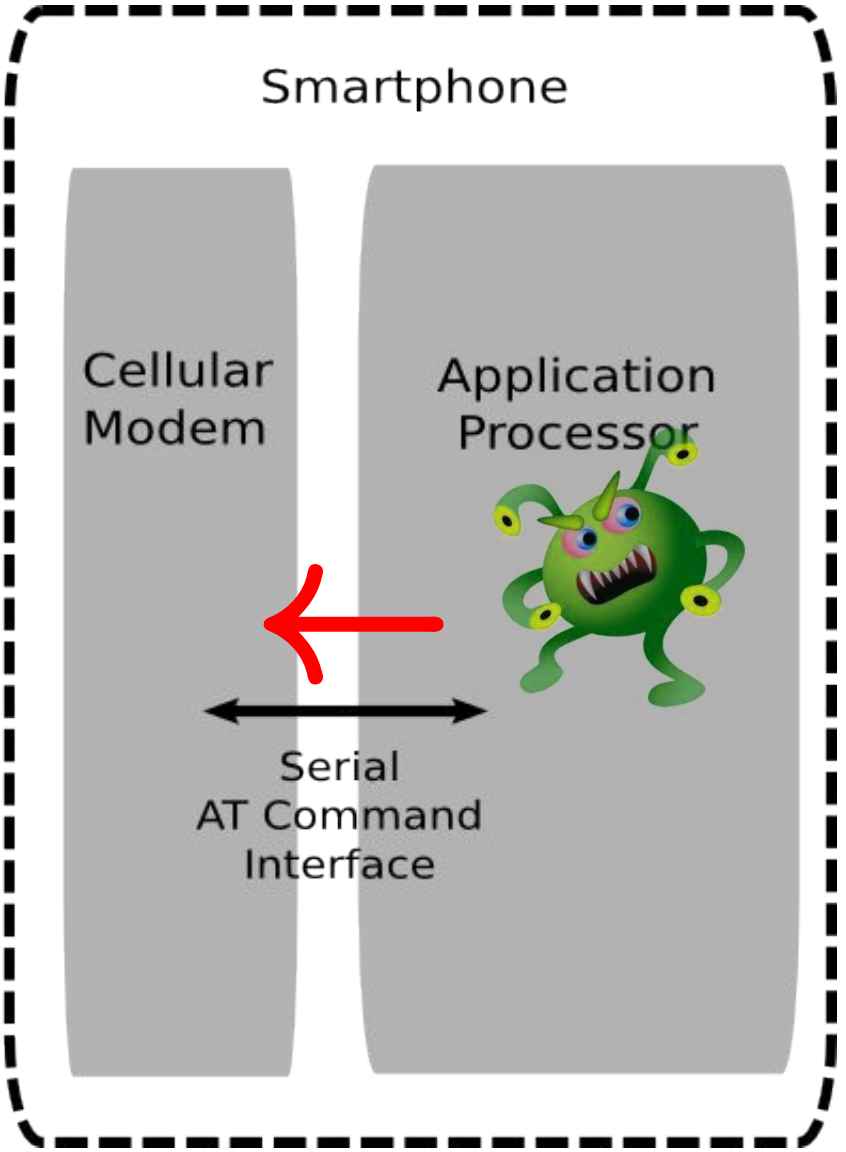
- **Categorization of Signaling Issues**
  - We investigated different types of signaling issues
- **Cellular Signaling Filter**
  - Designed, implemented, and evaluated a signaling filter
  - The filter is deployed and executed on the smartphone
- **Safe-to-root virtualized Android**
  - Our system works even when the smartphone OS is rooted!

Signaling Attacks

- DoS attack against cell network
  - Hijacked smartphones
- “Knockout” HLR (user DB)
  - Massively issue “insert call forwarding” command

On Cellular Botnets (CCS 2009 Traynor et al)

- Overload Packet-data network
  - Massively create / destroy PDP context



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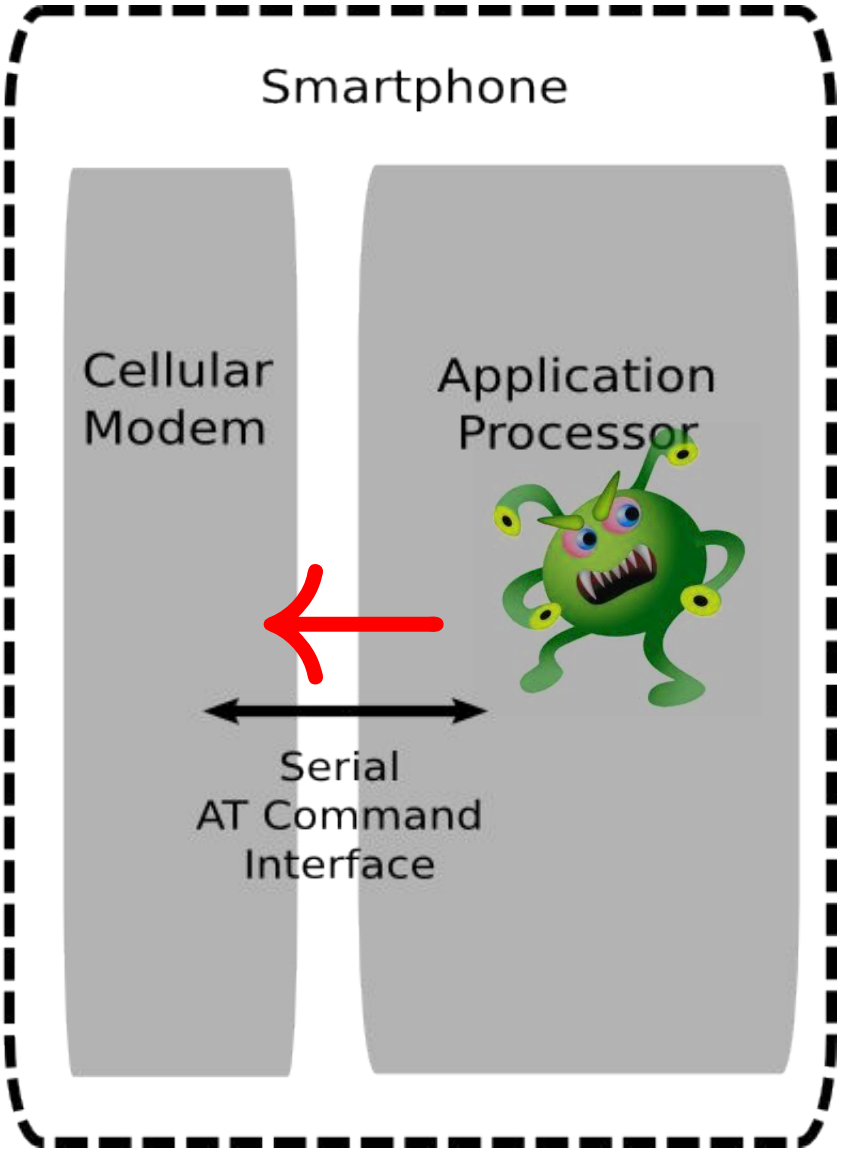
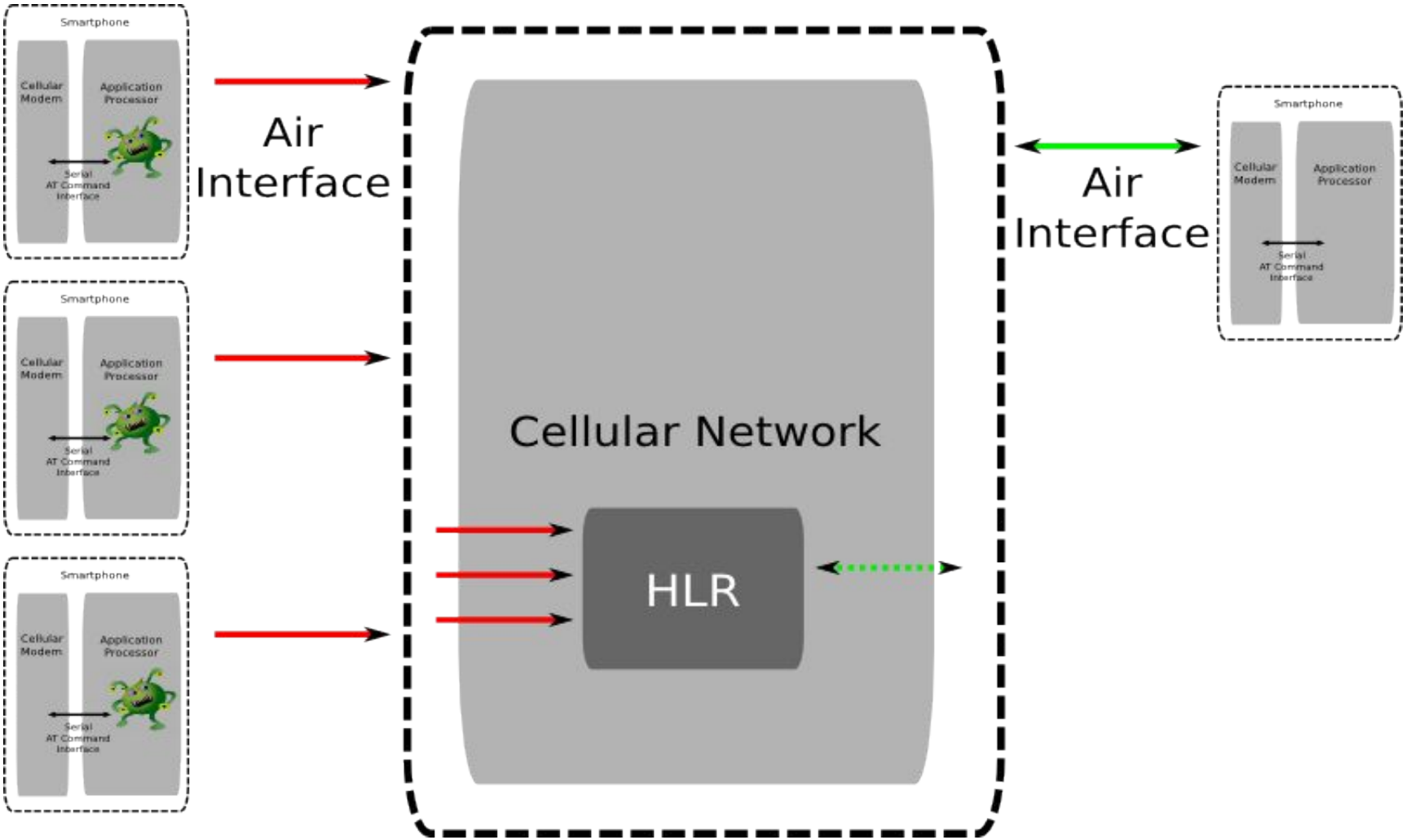


A Signaling Attack: HLR DoS



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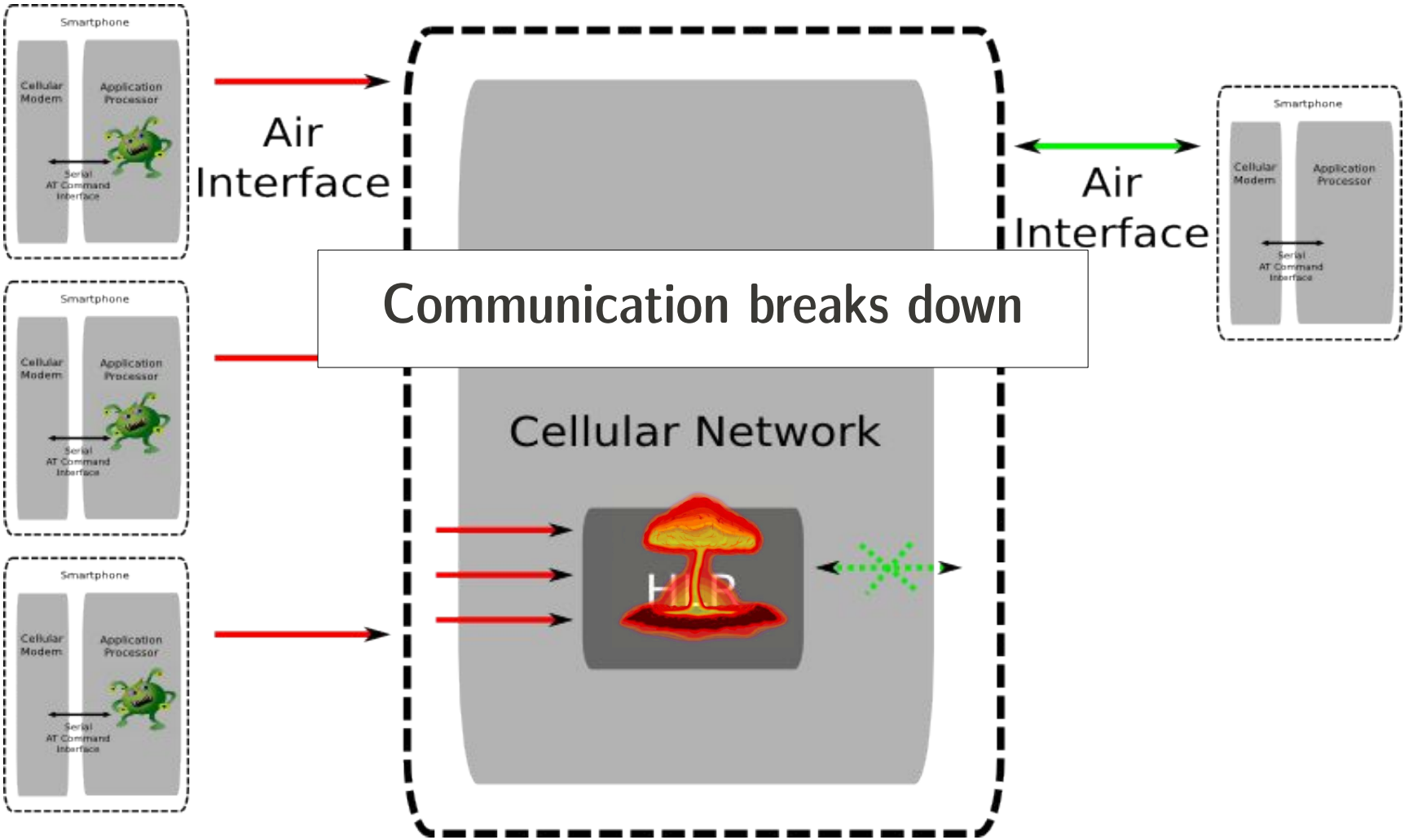
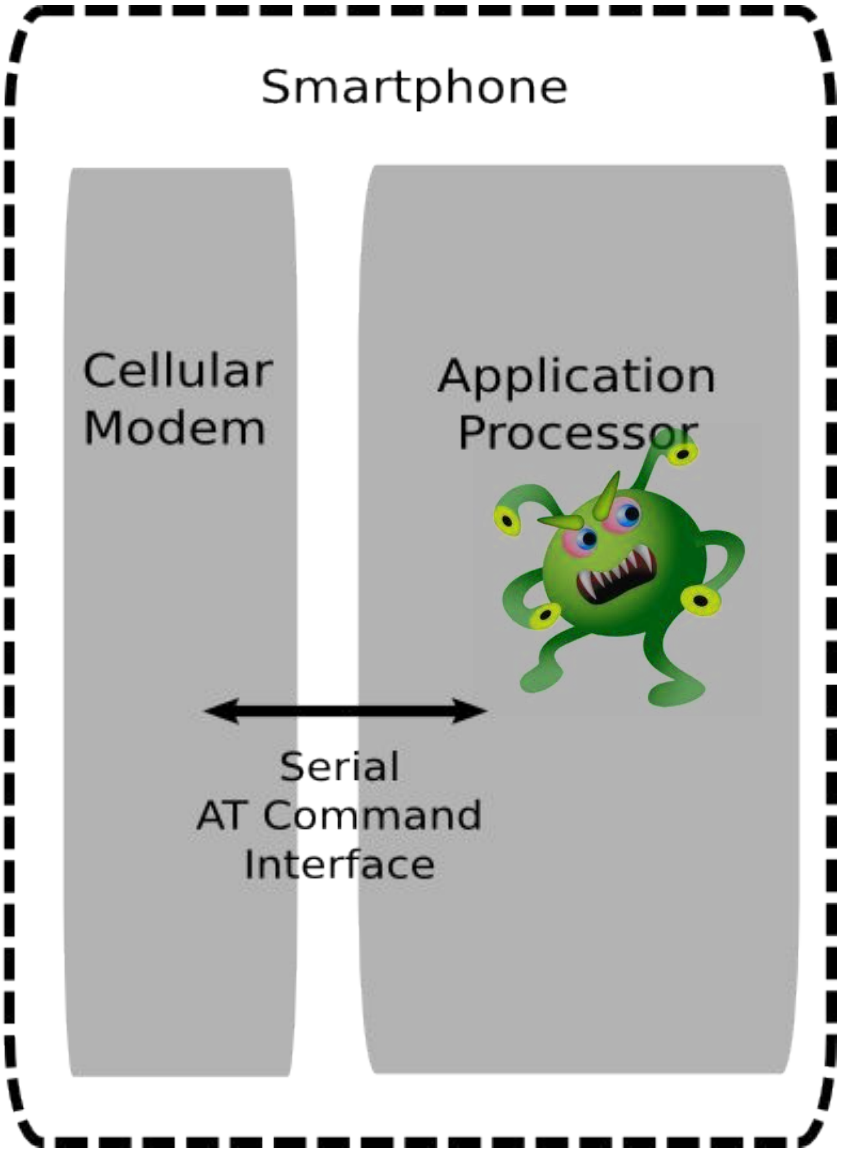
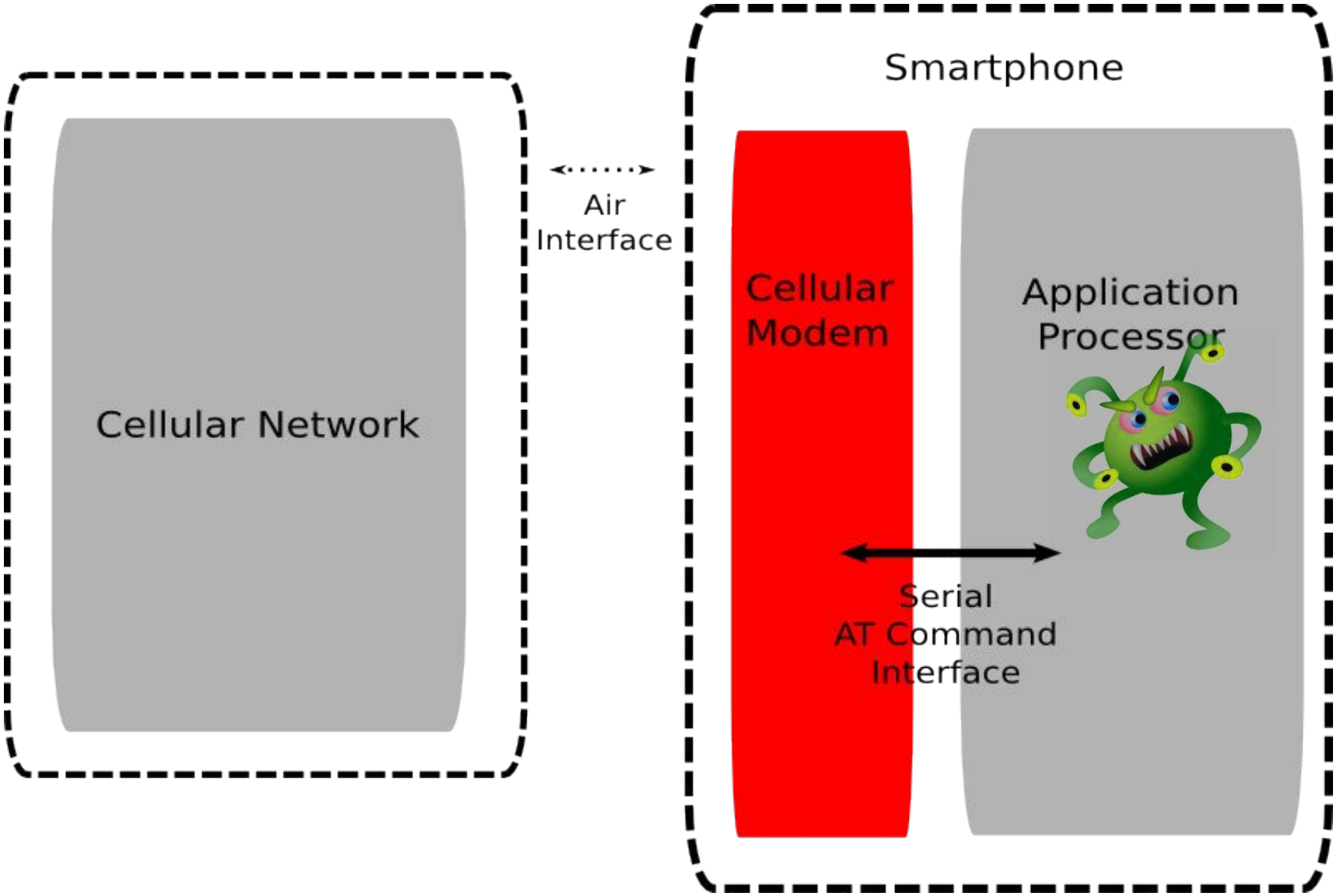


Signaling Attacks work because...

- Permission just deny/grant access to cellular modem
  - Users always say “yes”
- “Rooted” devices
  - Permissions are worthless
- Cellular modem is not protected

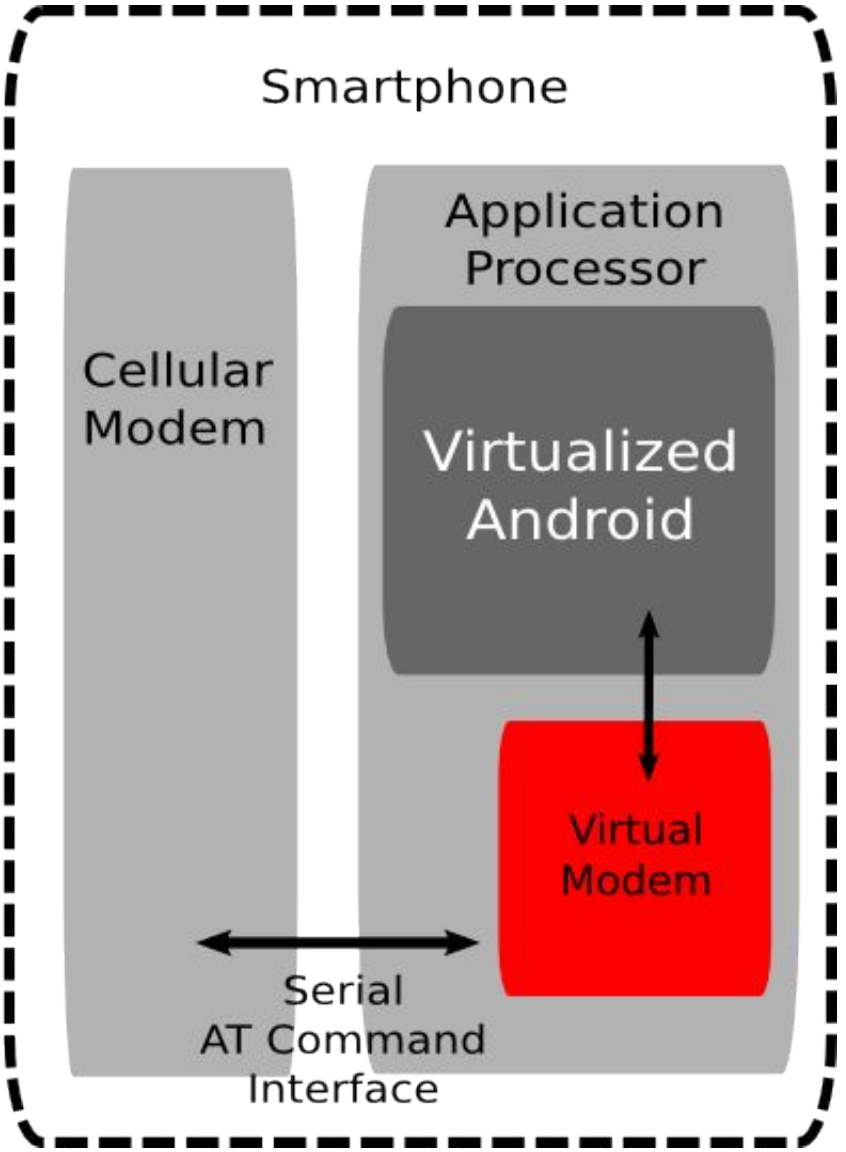


Stop “Malware” from abusing the Modem



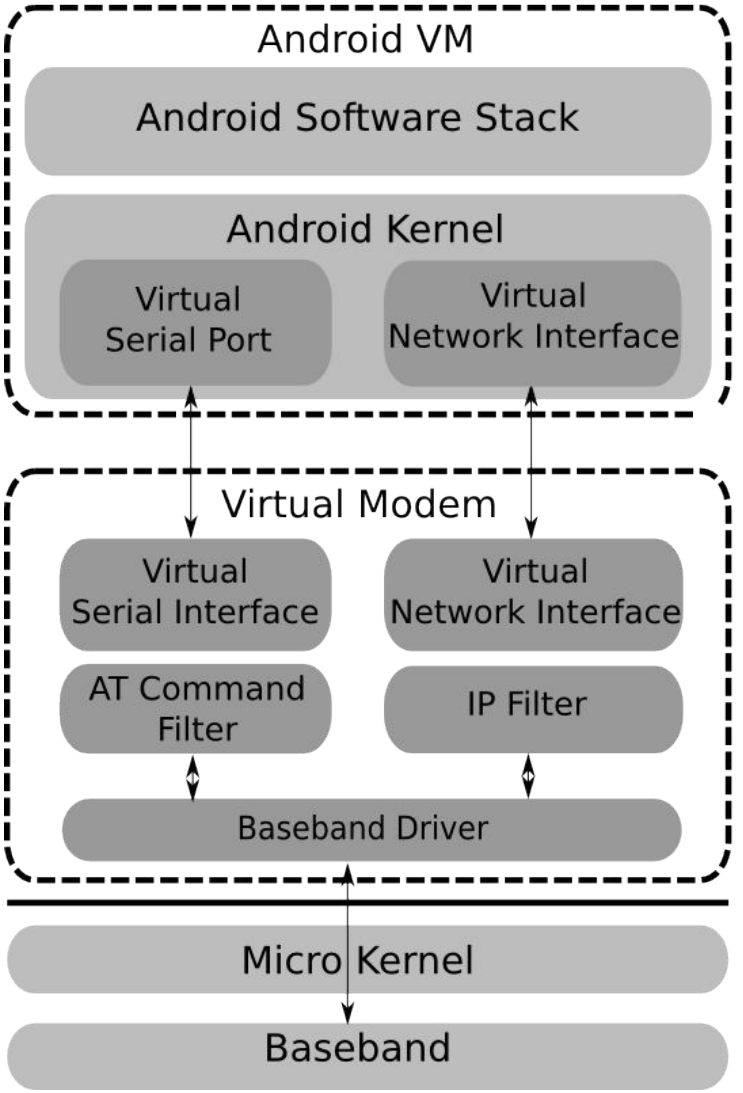
Our solution: The Virtual Modem

- Connects to real modem
- Provides modem interface to virtualized Android phone
- Resilient against rooting
  - Android VM cannot access modem directly



System Architecture

- L4 Fiasco.OC micro kernel
  - Hypervisor
- Virtual Modem
  - L4Linux with minimal userland
  - Contains modem driver
- Android VM
  - Android + L4Linux = L4Android*
  - Custom RIL for virtual modem

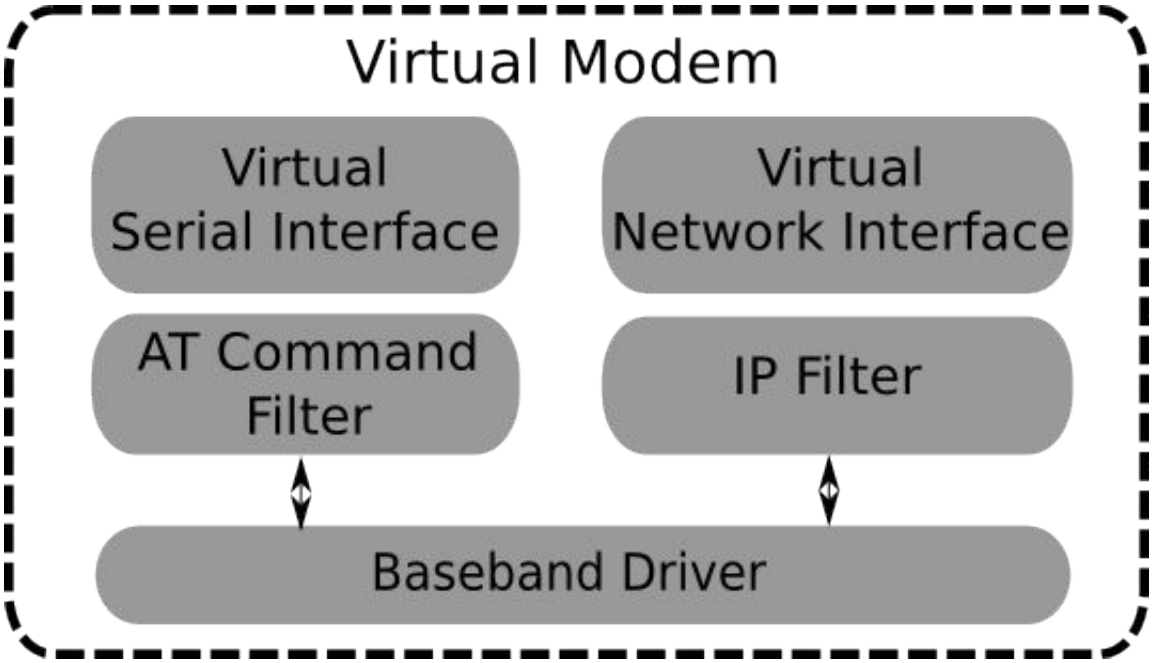


*http://www.L4Android.org

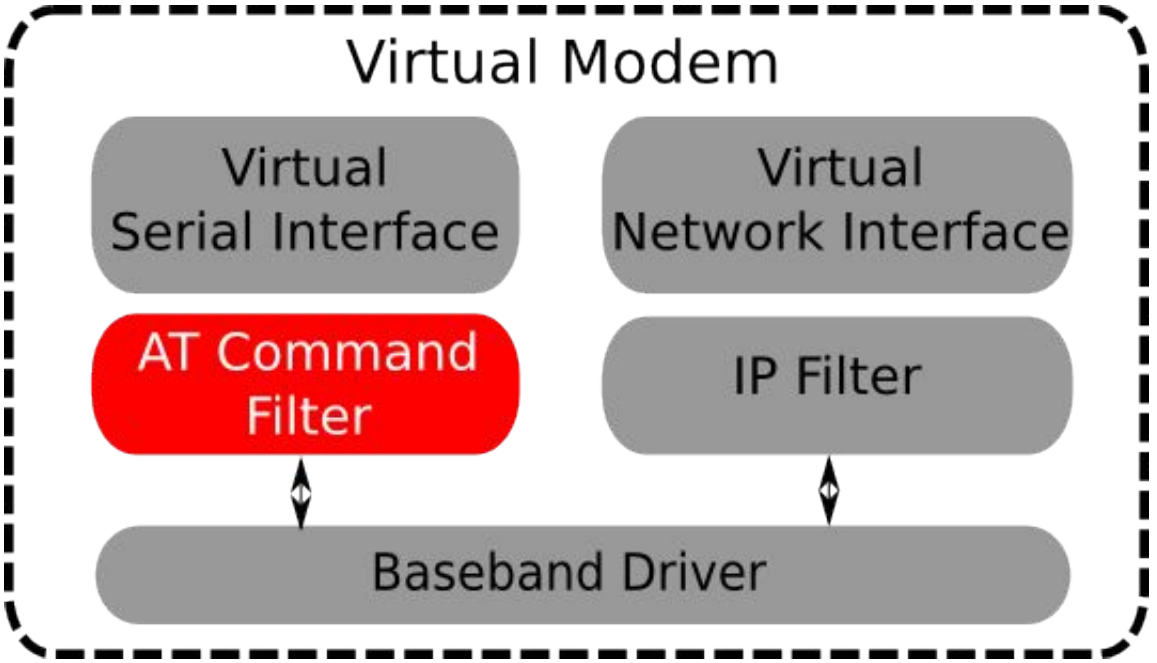
Development Target

- AAVA dev phone
  - x86 moorestown CPU
- Modem interface
  - GSM AT commands (this is common!)

Inside the Virtual Modem



The AT Command Filter



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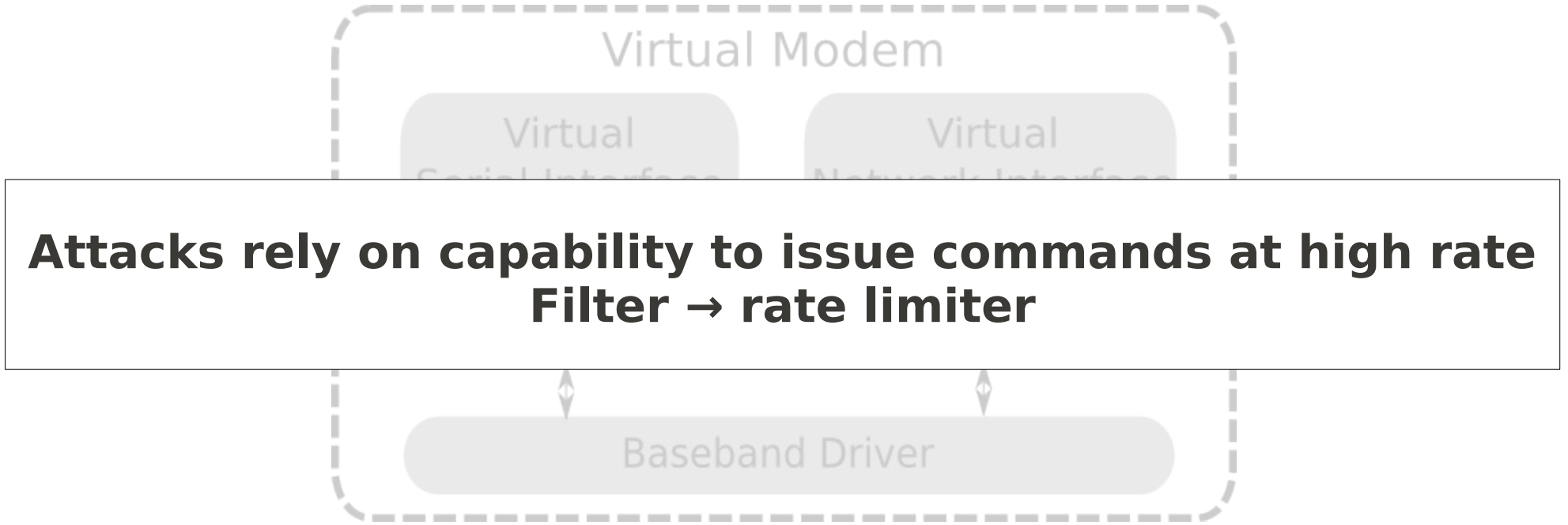

Attacks rely on capability to issue commands at high rate
Filter → rate limiter

Commands to filter

- Command → Signal → Attack

- Signaling relevant commands

  Packet-Data : AT+CFUN, AT+CDGMNT, AT*EPPSD

  HLR : AT+CCFC

  SMS : AT+CMGS

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- Signaling relevant commands

  Packet-Data : AT+CFUN, AT+CDGMNT, AT*EPPSD

  HLR : AT+CCFC

  SMS : AT+CMGS

AT Command Usage under “normal” Conditions

Command	#	When	Why
AT+CFUN	2	Boot	Flight mode. Normal mode.
AT+CFUN	1	Use	Switch to GSM-only.
AT+CDGMNT	1	Boot	Set PDP configuration.
AT*EPPSD	1	Boot	Activate PDP context.
AT+CMGS	1	Use	Send a SMS message.
ATD	1	Use	Issue a voice call.
AT+CCFC	3	Use	Query forwarding settings.
AT+CCFC	2	Use	Set a call-forwarding.

The HLR Attack Setup

- Numbers taken from *"On Cellular Botnets"*
  - Access to number of actual setup very hard
  - We evaluated against the attack described in:

    P. Traynor, M. Lin, M. Ongtang, V. Rao, T. Jaeger, T. La Porta, and P. McDaniel. On Cellular Botnets: Measuring the Impact of Malicious Devices on a Cellular Network Core. In ACM Conference on Computer and Communications Security (CCS), November 2009.

- Simulated HLR supported 1 million users

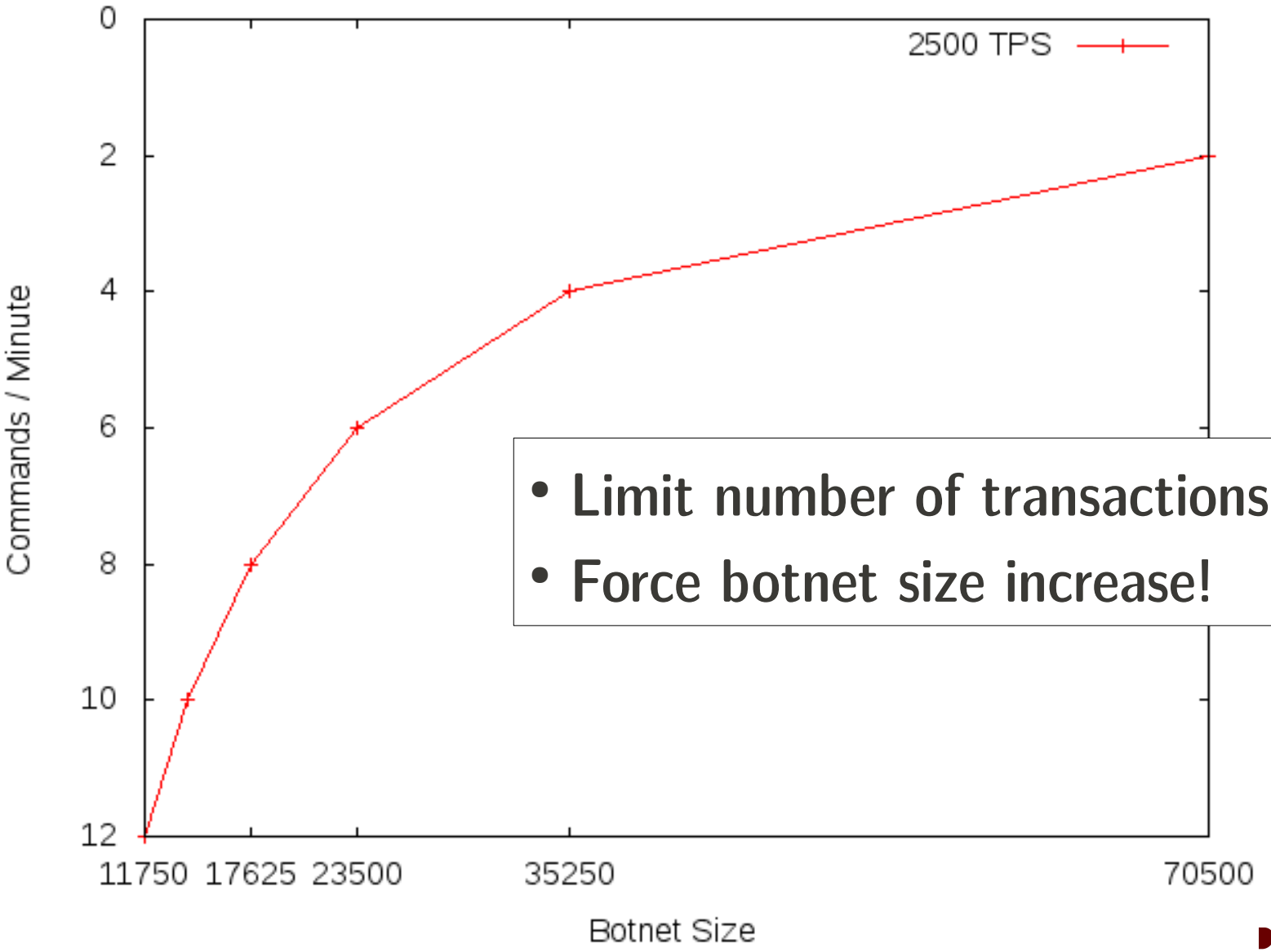
The HLR DoS Attack

- HLR collapse at 2500 transactions per second (TPS)
  - 2500 TPS relate to example HLR setup and network size
- 4.7 seconds/transaction = ~12 transactions/minute

  → 11750 bots required for attack
- 12 transaction/minute → maximum possible speed

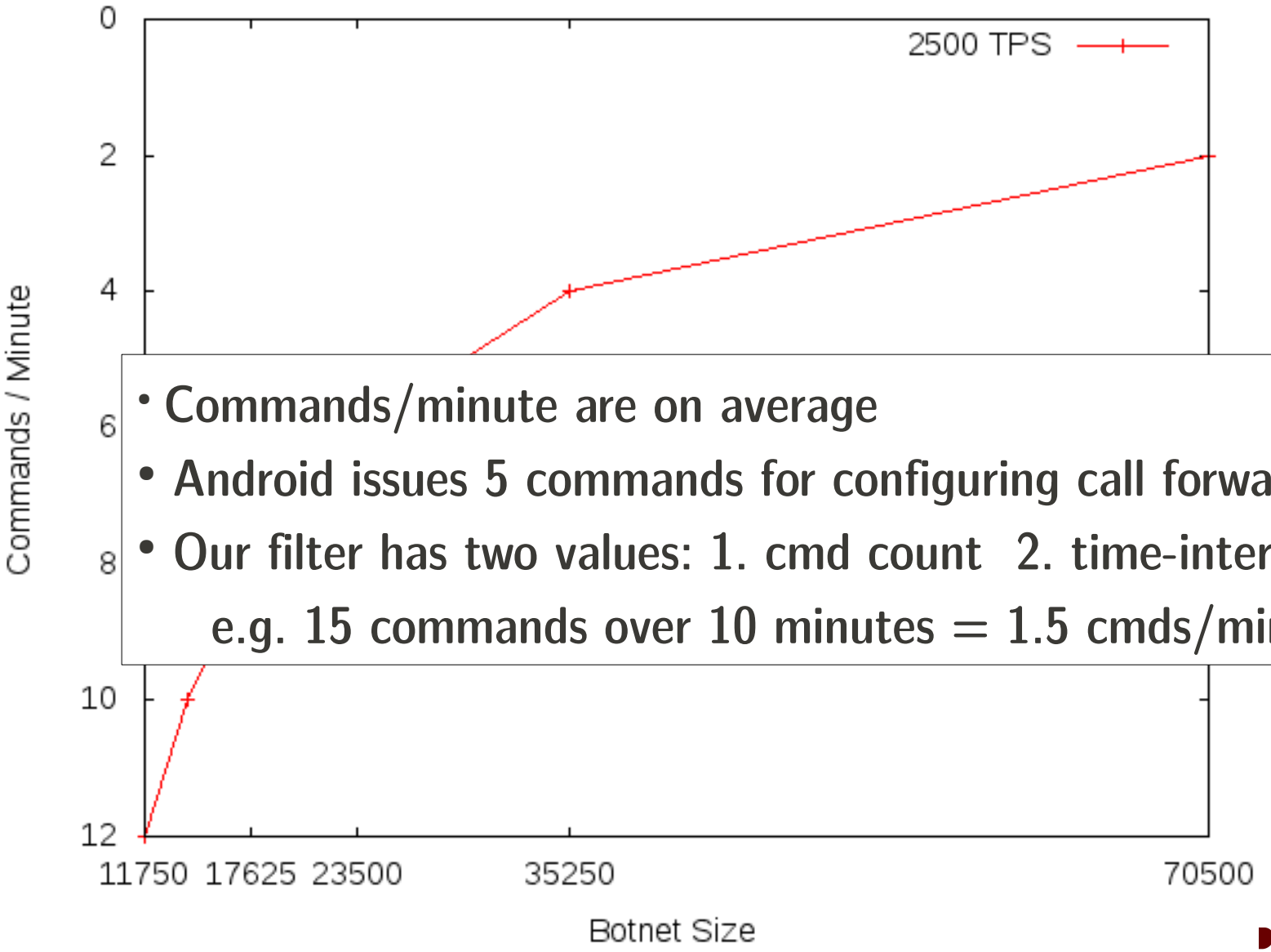
  → Number of commands/minute, can only issue one after another

Preventing the HLR DoS Attack



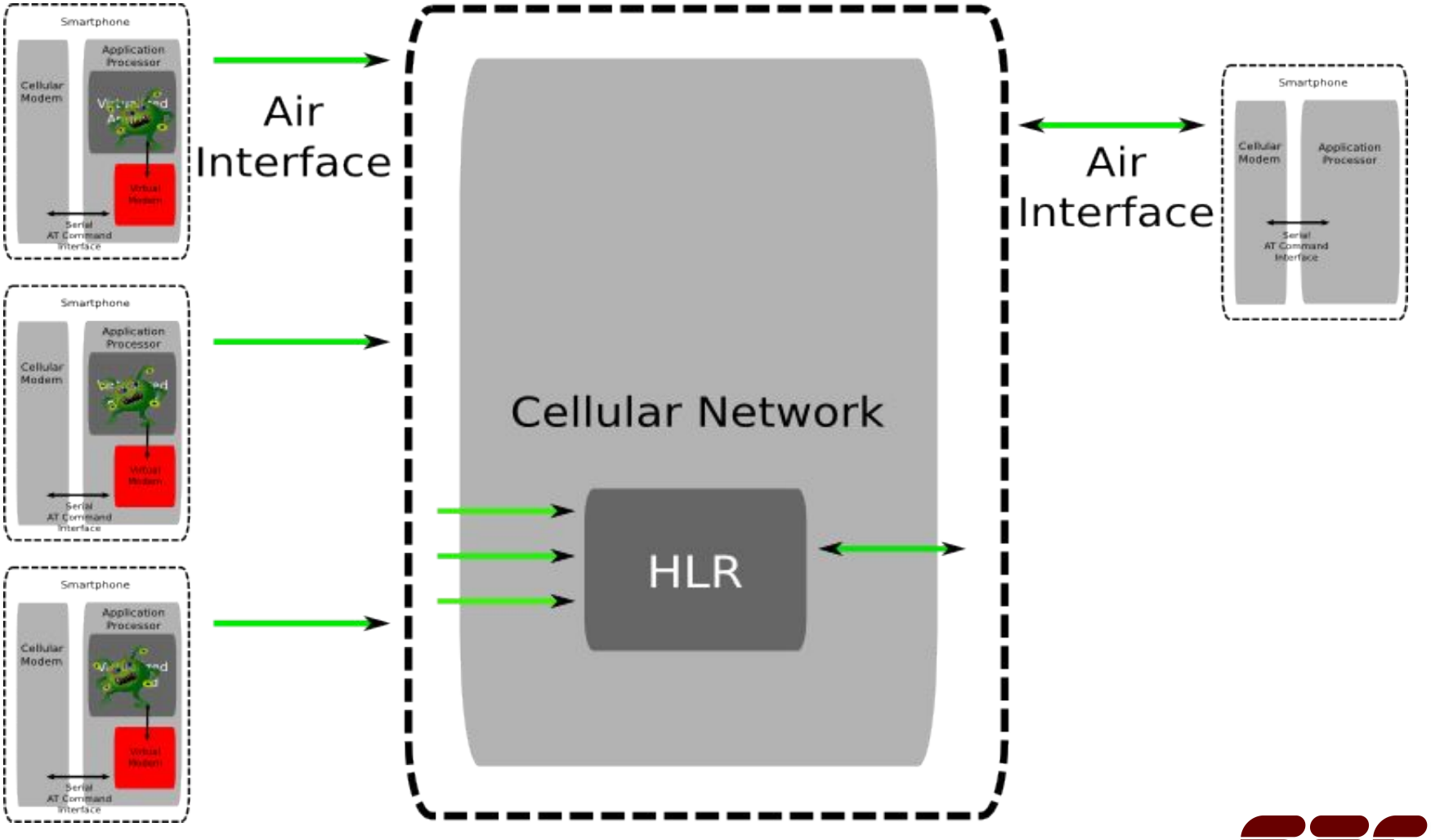
- Limit number of transactions/minute
- Force botnet size increase!

Preventing the HLR DoS Attack



- Commands/minute are on average
- Android issues 5 commands for configuring call forwarding
- Our filter has two values: 1. cmd count 2. time-interval
  e.g. 15 commands over 10 minutes = 1.5 cmds/minute

Our Virtual Modem protects the Network



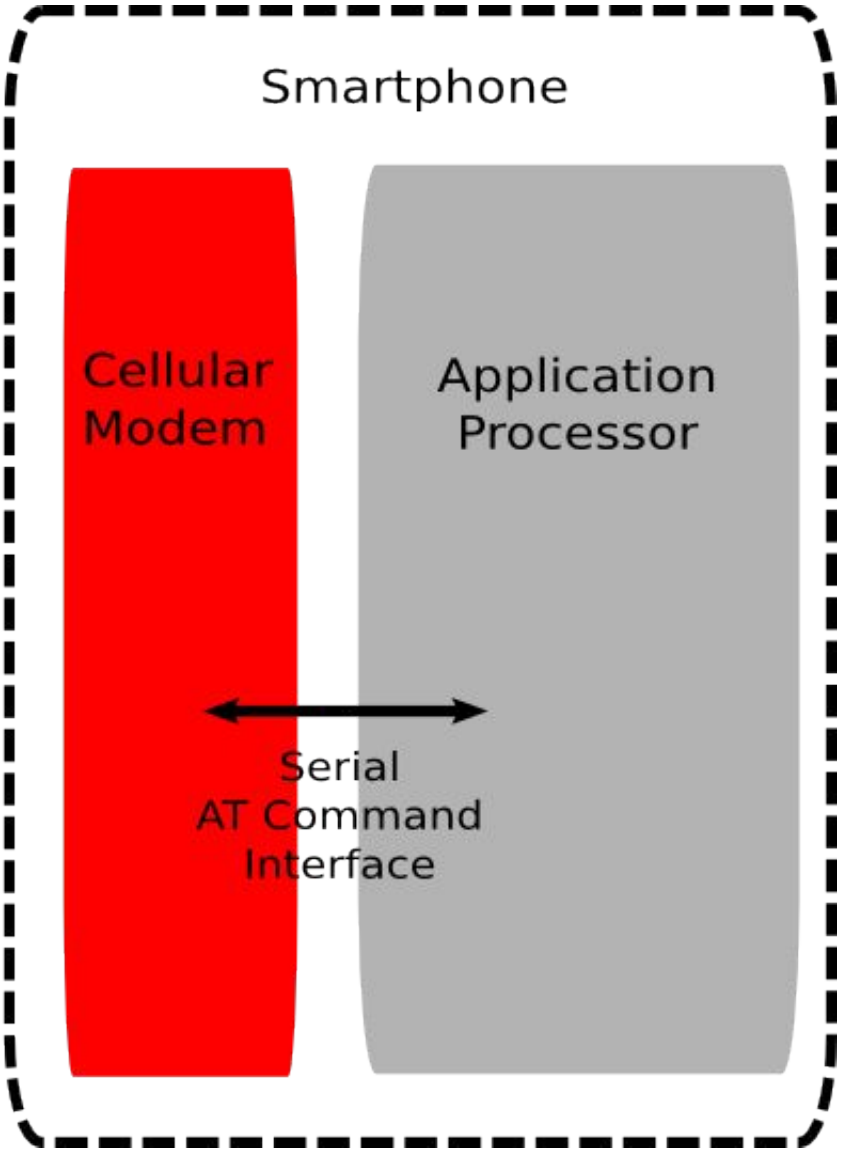
Virtual Modem further prevents...

- PDP-context switching Denial-of-Service attack
  - Similar filter rules as used to prevent HLR attack
- Prevent SMS-based C&C for mobile botnet
  - Detect and prevent large number of binary SMS messages
- Prevent Premium rate SMS fraud
  - Prevent sending SMS to “short codes”

Detail are in the paper.

Lessons learned...

- Modem is just a network interface
  - Can be abused by malware
- Modem is not protected
  - Permission systems are not enough
- Specialized protection required
  - Control usage of modem interface



Summary and Contributions

- Signaling Attacks are a serious problem for cellular networks
  - Various kinds of signaling related attacks
  - Easy to execute using hijacked smartphones

- Our Virtual Modem mitigates
  - Signaling Attacks
  - SMS-based fraud and botnets

- System architecture resilient against rooting
  - Android OS and policy enforcement are separated

Virtual Modem ported to current Smartphones

- **Smartphone virtualization for security is an ongoing project**

- Now also runs on
  - Samsung Galaxy S II

Q & A

Thank you for your attention!

Questions?

Future Work

- VPN in virtual modem
  - secure credentials if system is hijacked and rooted
- Advanced IPS / IDS in virtual modem
  - vmodem can monitor and/or block IP traffic
- Policy update infrastructure
  - System to update and modify vmodem policy from network
- Secure GUI
  - Ask user for permission for some actions
- Hardware virtualization
  - Make use of HW virtualization support to improve performance