Chair of Network Architectures and Services
Department of Informatics
Technical University of Munich

Privacy Assessment using Static Taint Analysis (Tool Paper)

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June 20th 2017

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What is Privacy?

- Unlinkability
  - Impossibility to combine present information gain further information
- Transparency
  - Users can gain insight into processes and software architectures
- Intervenability
  - Data subjects (users): be in control over their data and exercise their user rights
  - Process owners (providers): be in control of their technical systems

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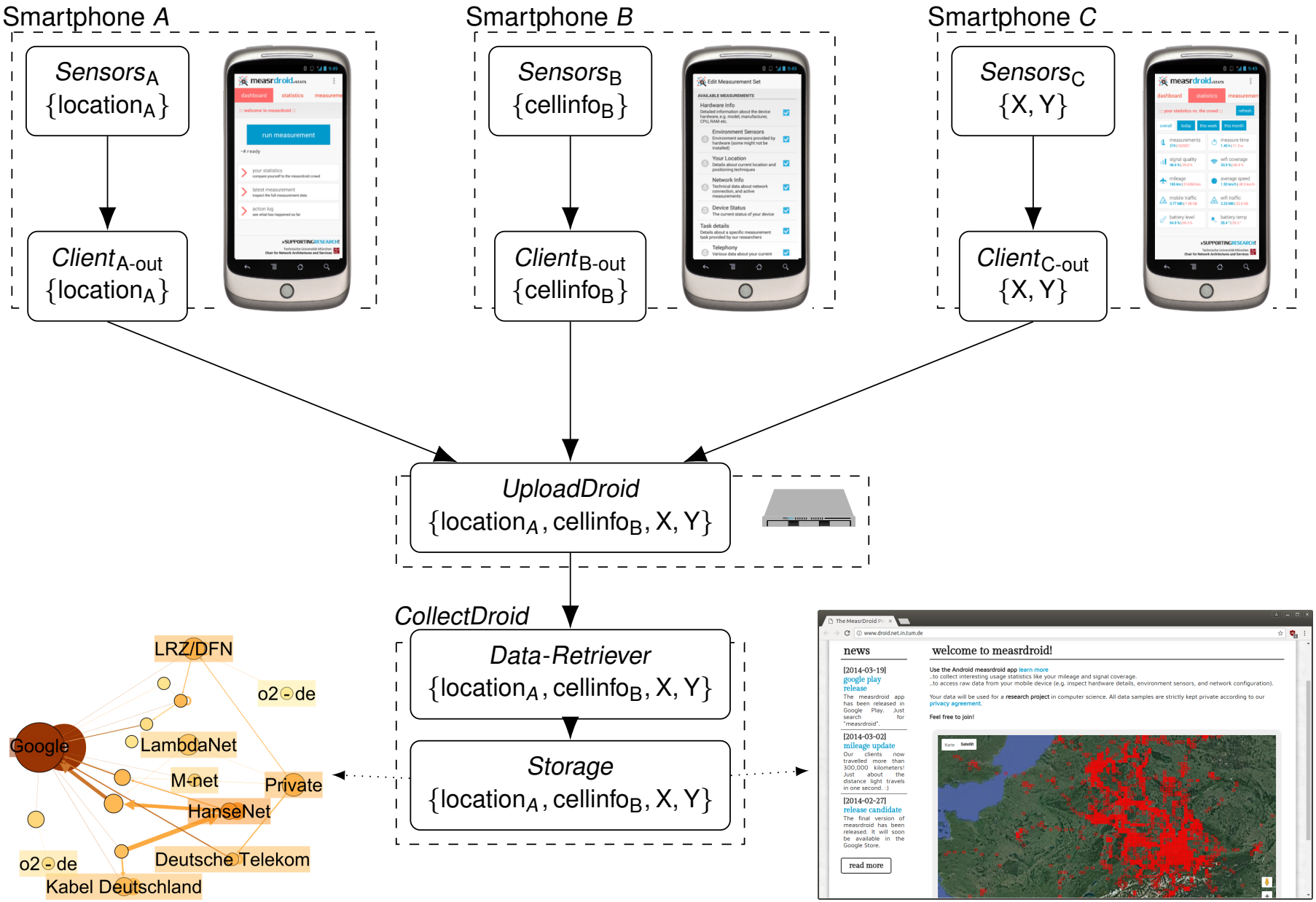
Compatible with Pfitzmann and Rost [11], Steinbrecher [12], Bock and Rost [2], Bock, Rost, and Pfitzmann [5], German Standardized Data Protection Model [1], Global Privacy Standard [3], Privacy by Design [4], Hoepman [10]

Example Scenario



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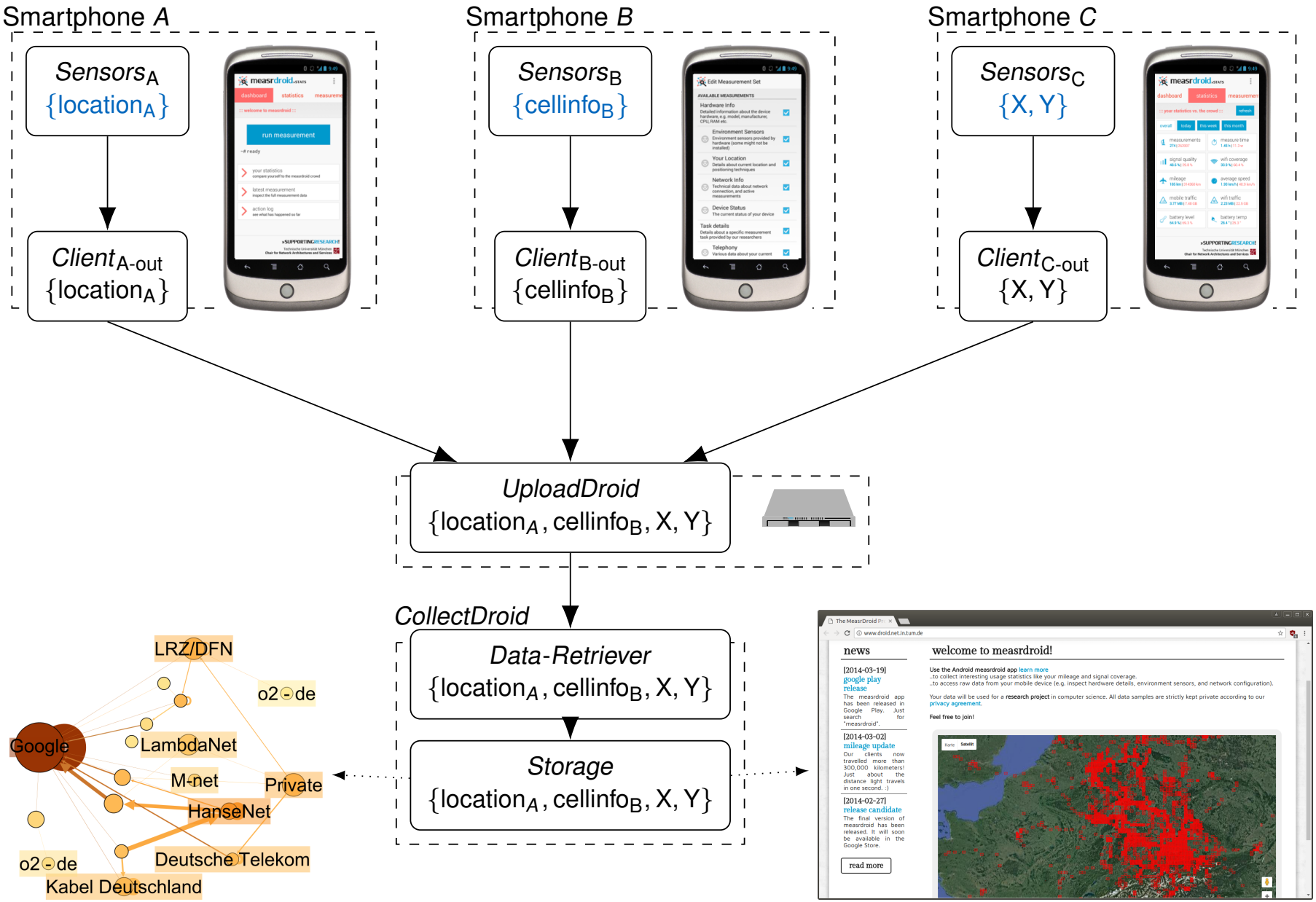

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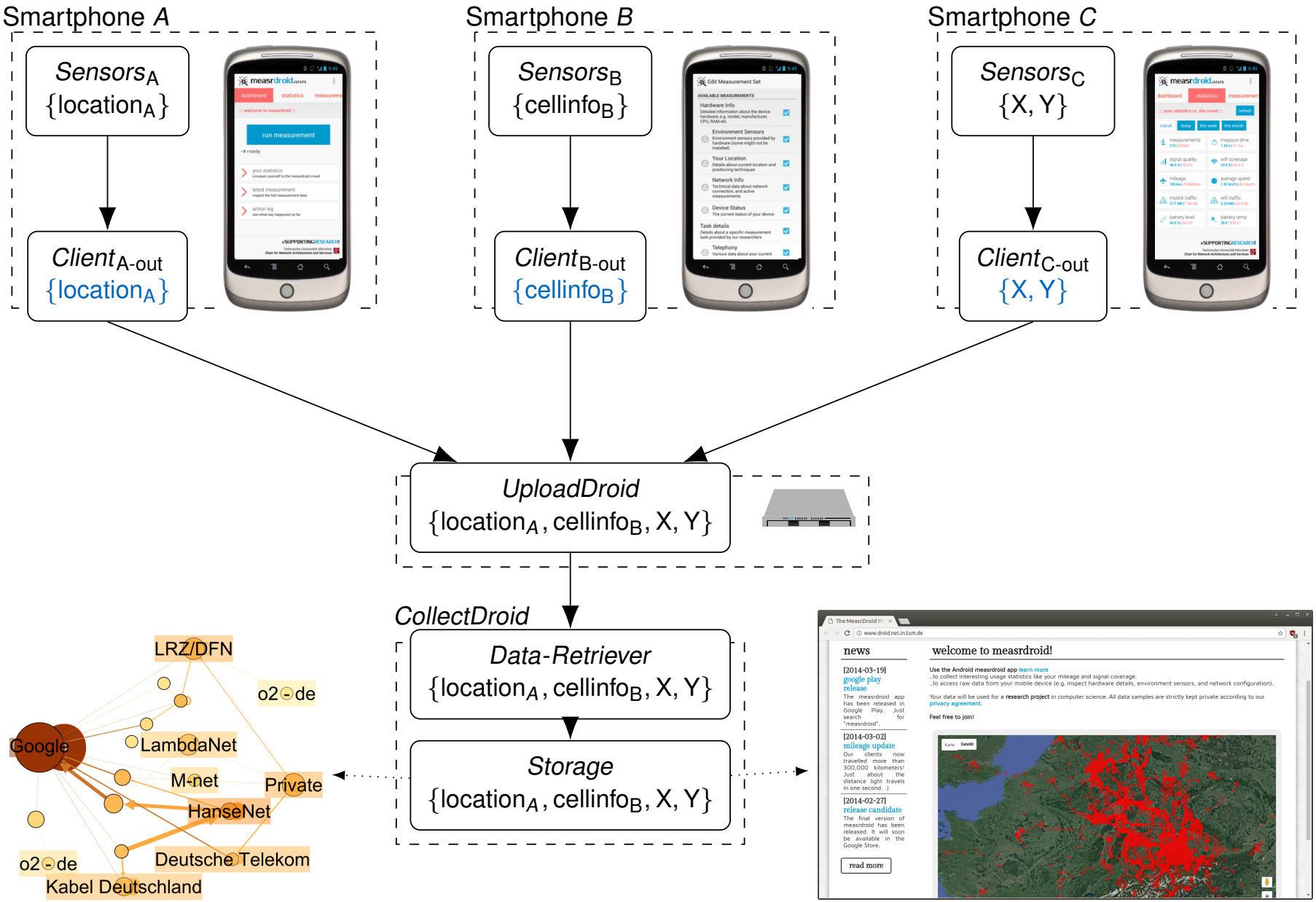

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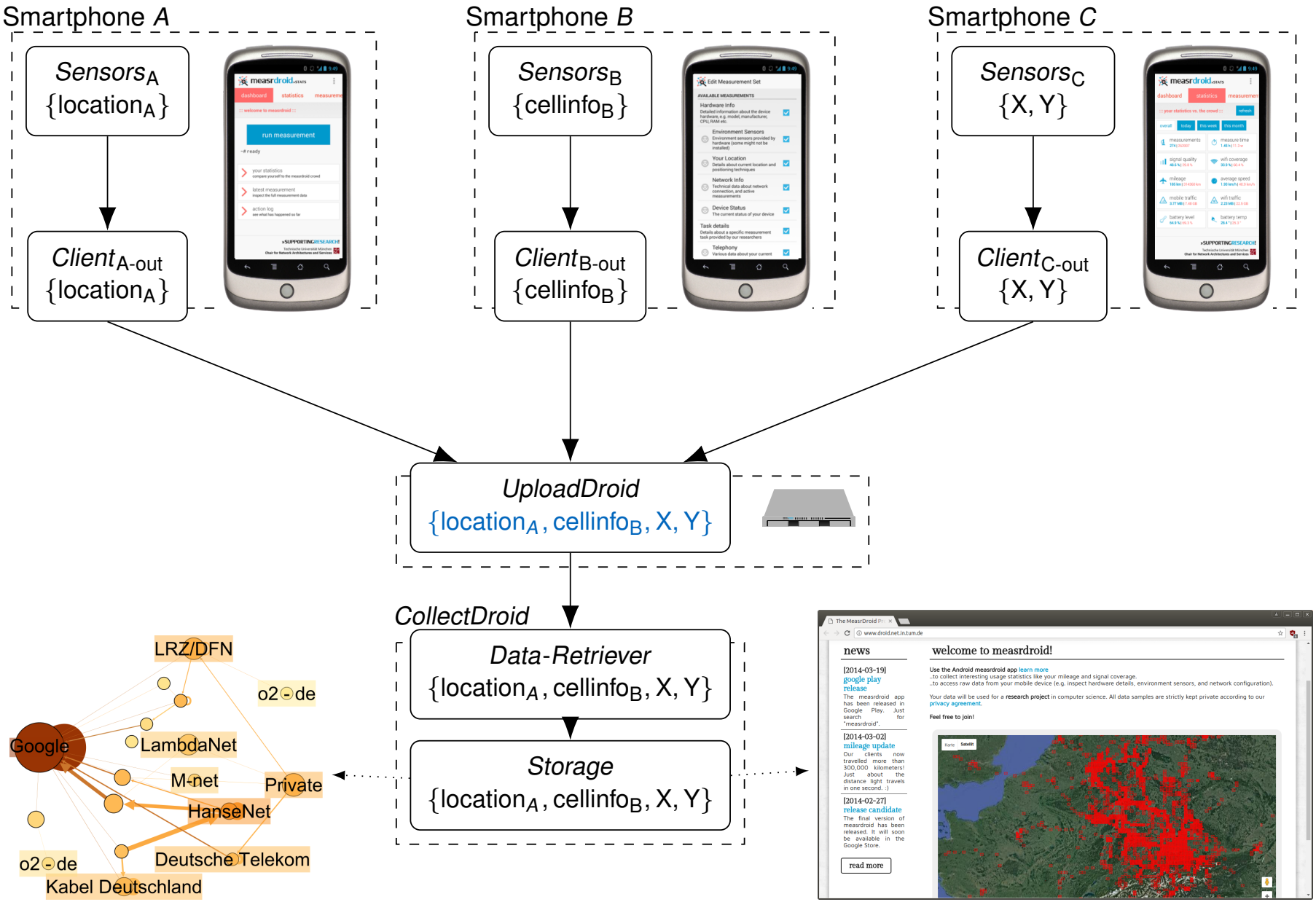

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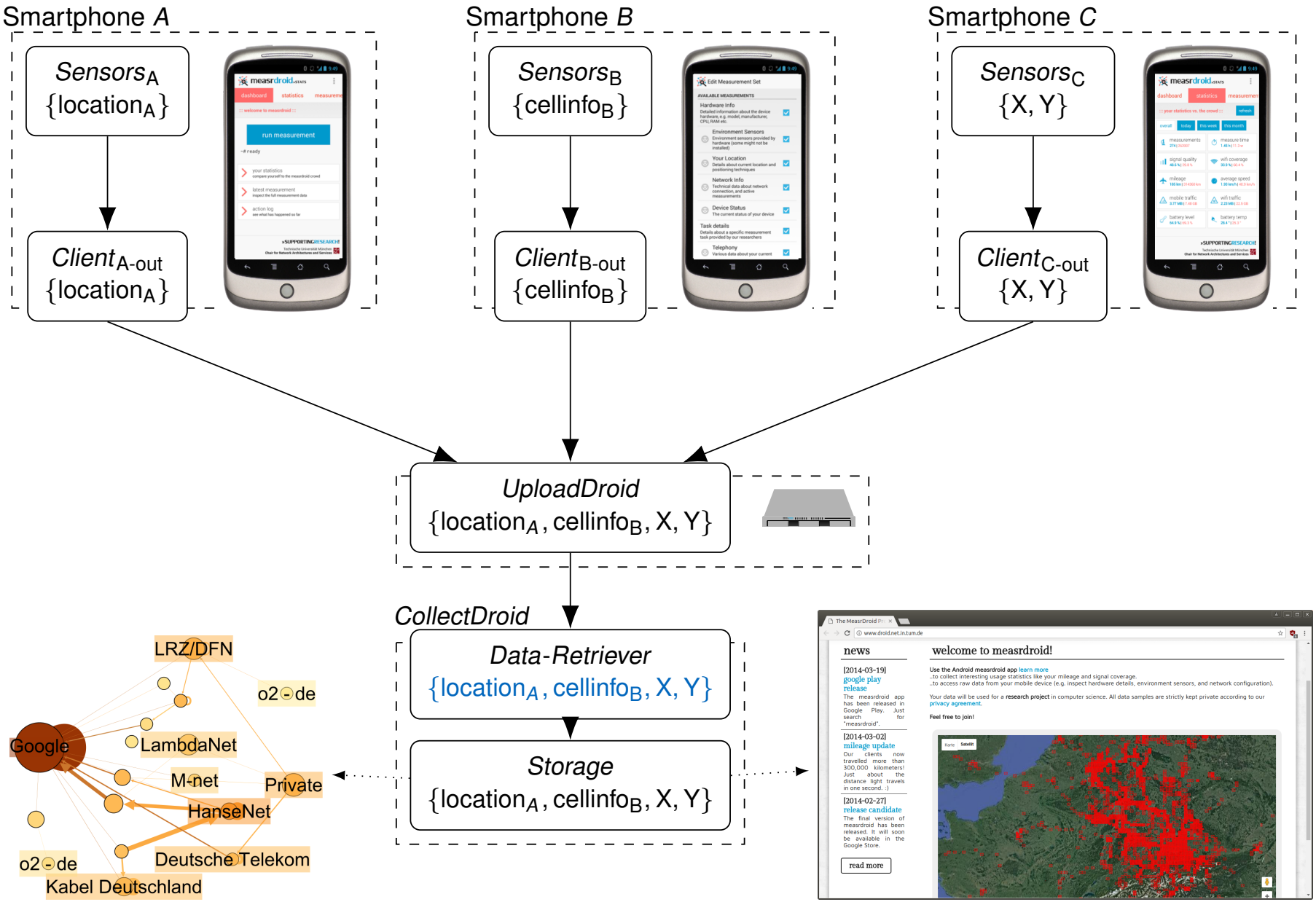

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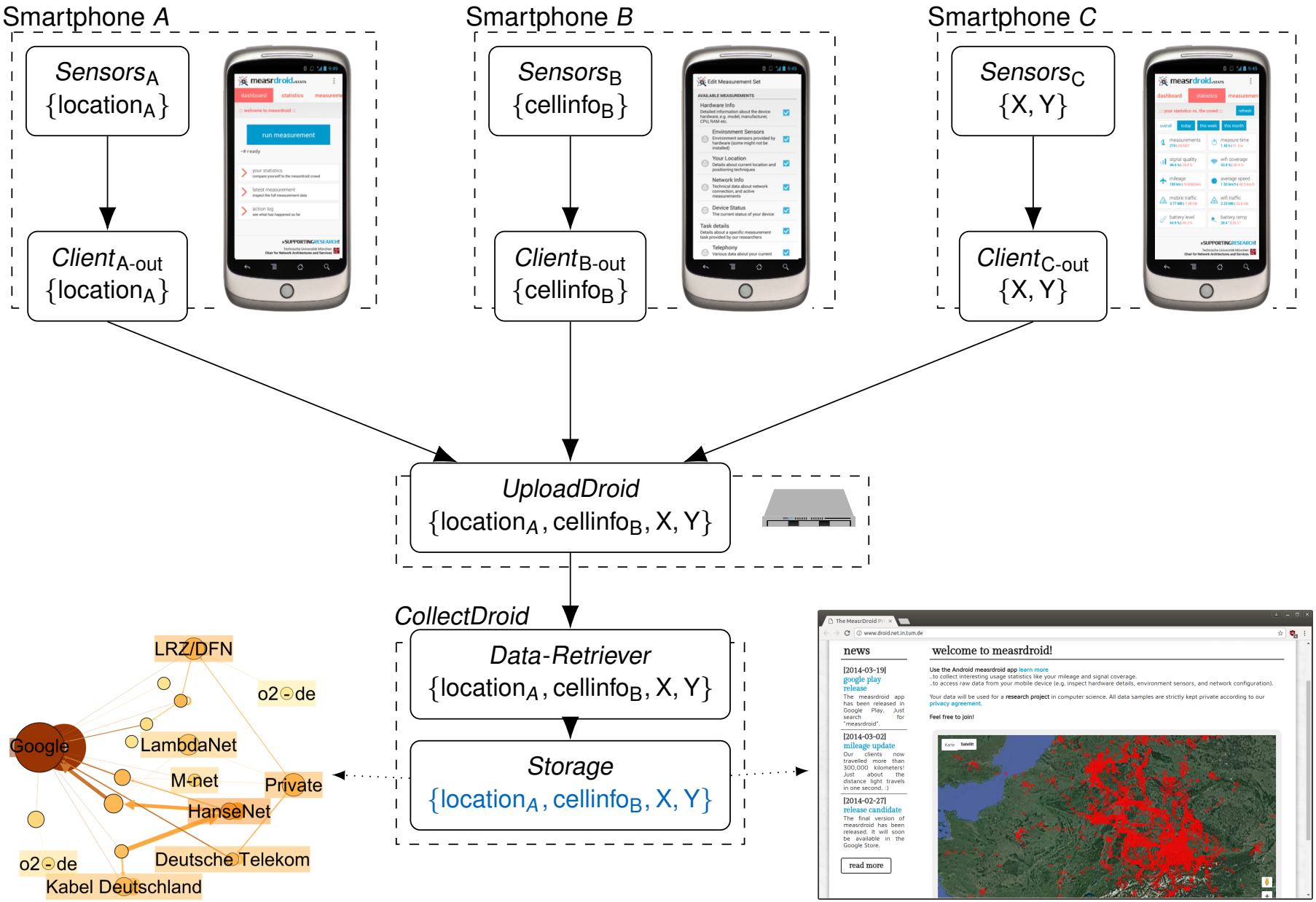

Formalizing Taint Analysis

- Graph $G = (V, E)$
- Total function $t :: \mathcal{V} \Rightarrow \textit{taintlabel set}$
  - Example: $t\ \textit{Storage} = \{\text{location}_A, \text{cellinfo}_B, \text{X}, \text{Y}\}$

$$\text{tainting}\ (V, E)\ t \equiv \forall v \in V.\ \forall r \in \{r.\ (v, r) \in E^+\}.\ \ t\ v \subseteq t\ r$$

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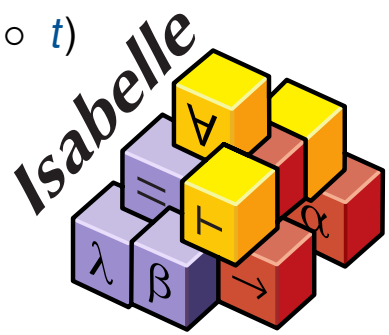

Approach

- Get your information flow as graph
- Add taint labels
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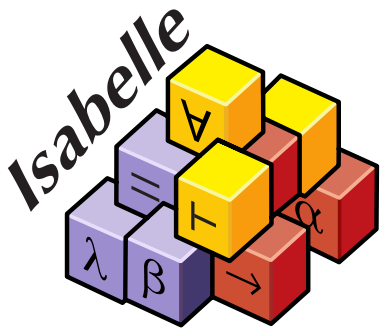


Rest of this talk: Auditing the real System!

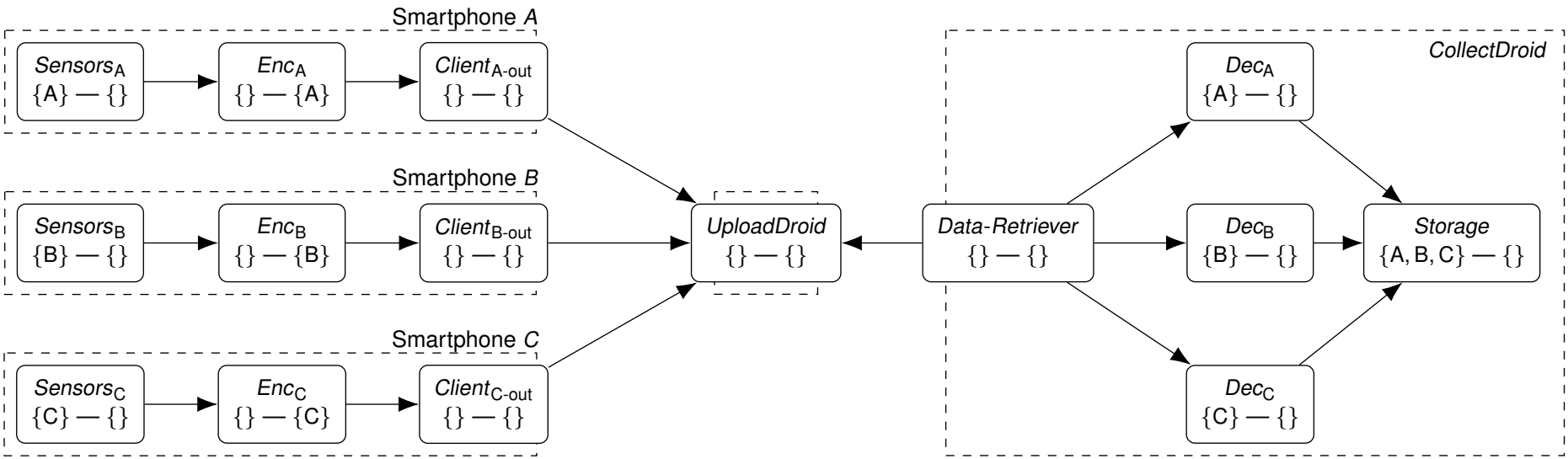
- Fully verified with Isabelle/HOL
- From abstract privacy concept to low level implementation
- Probably largest fully-verified real-world privacy audit of a firewall
- One example of a whole class of applications

Tools:

- topoS: policy analysis framework, enhanced with tainting
- fffuu: firewall analysis

MeasrDroid – Architecture Formalized

- System for collecting smartphone sensor data
- Deployed at TUM
- Syntax: {taints}—{untaints}



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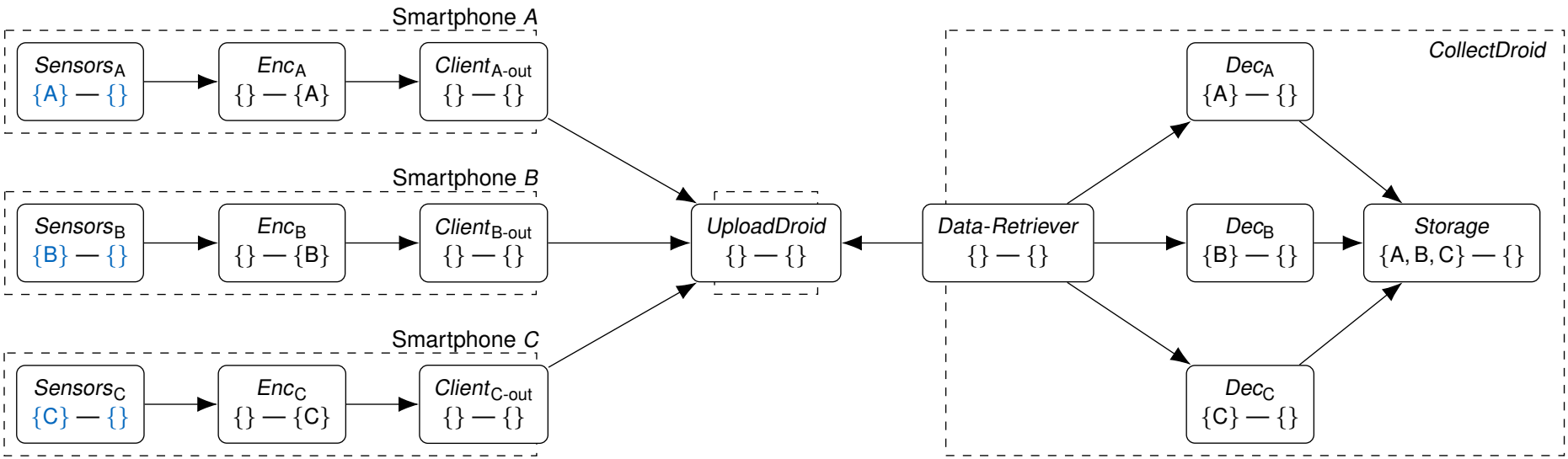

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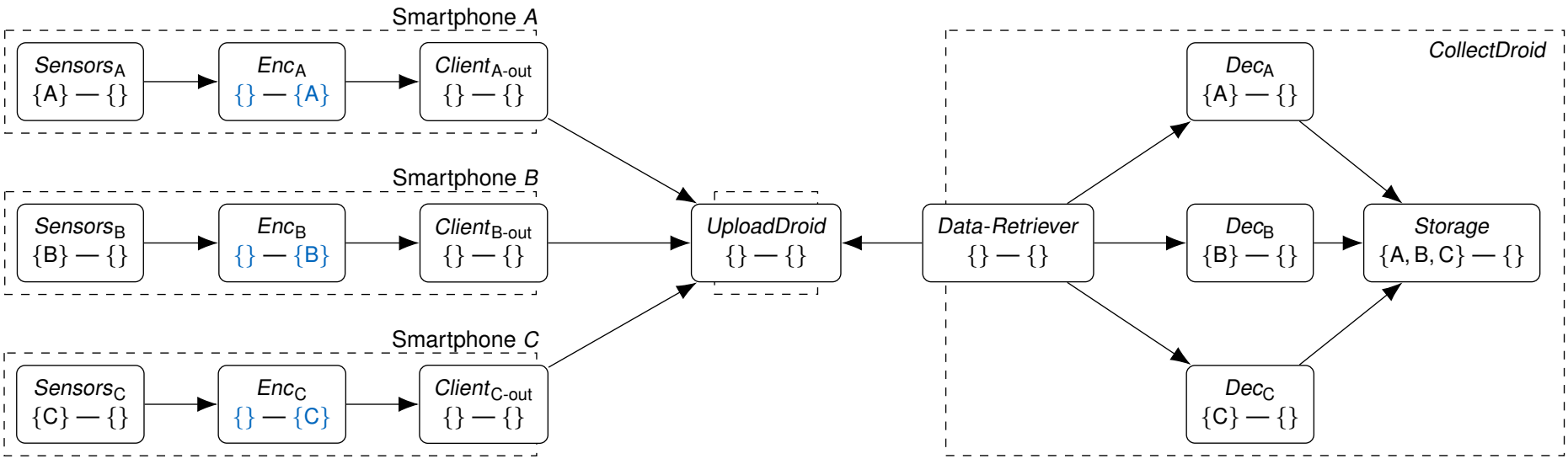

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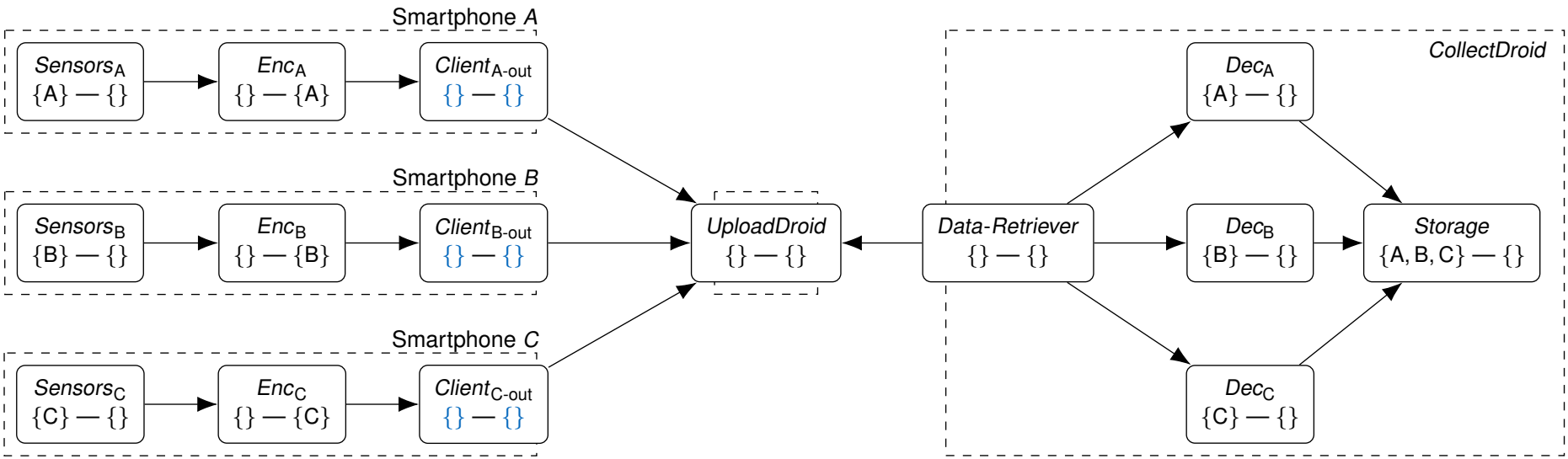

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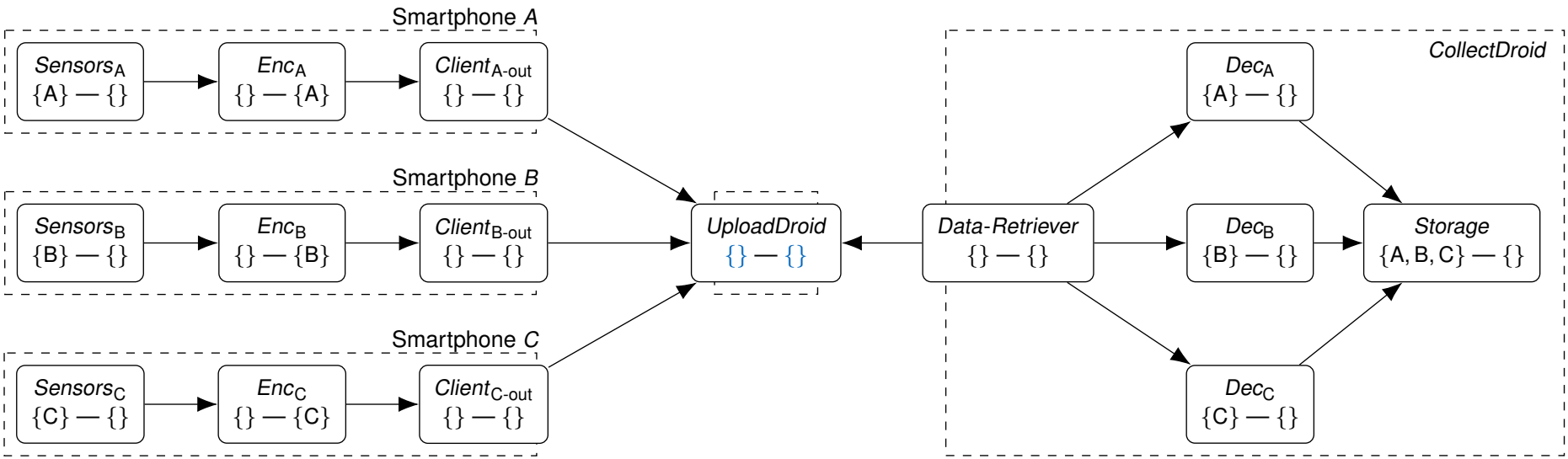

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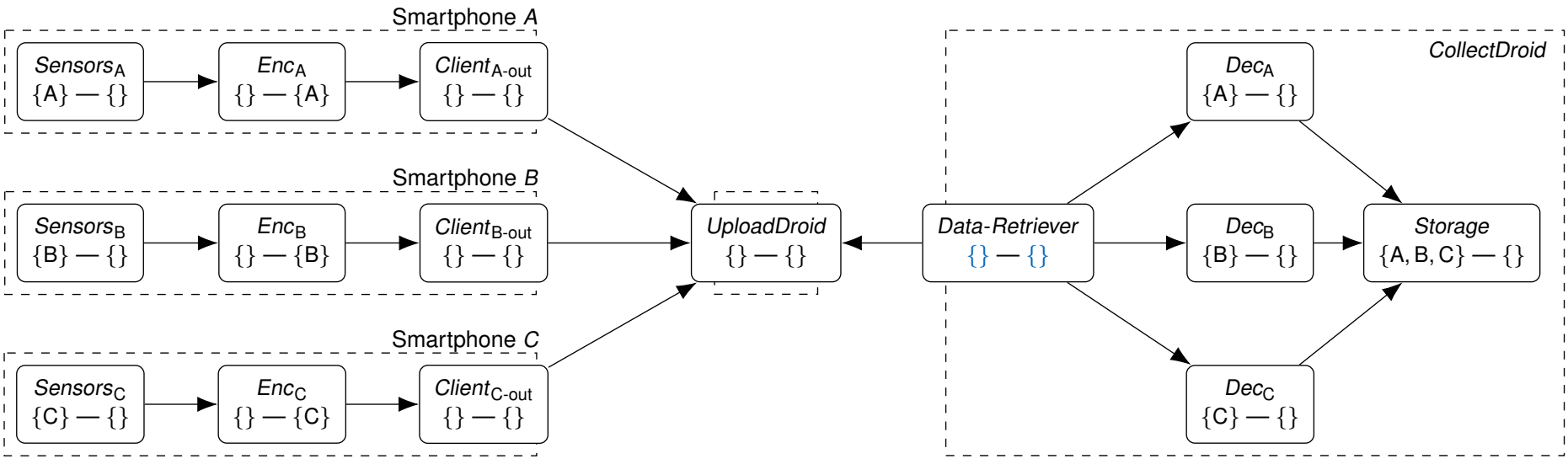

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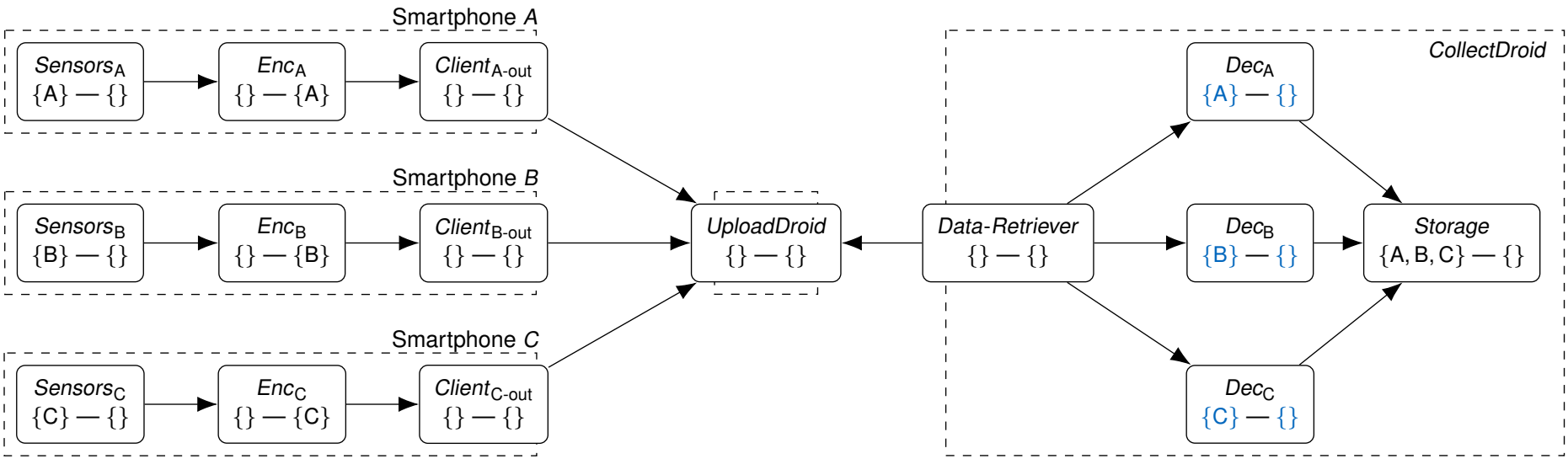

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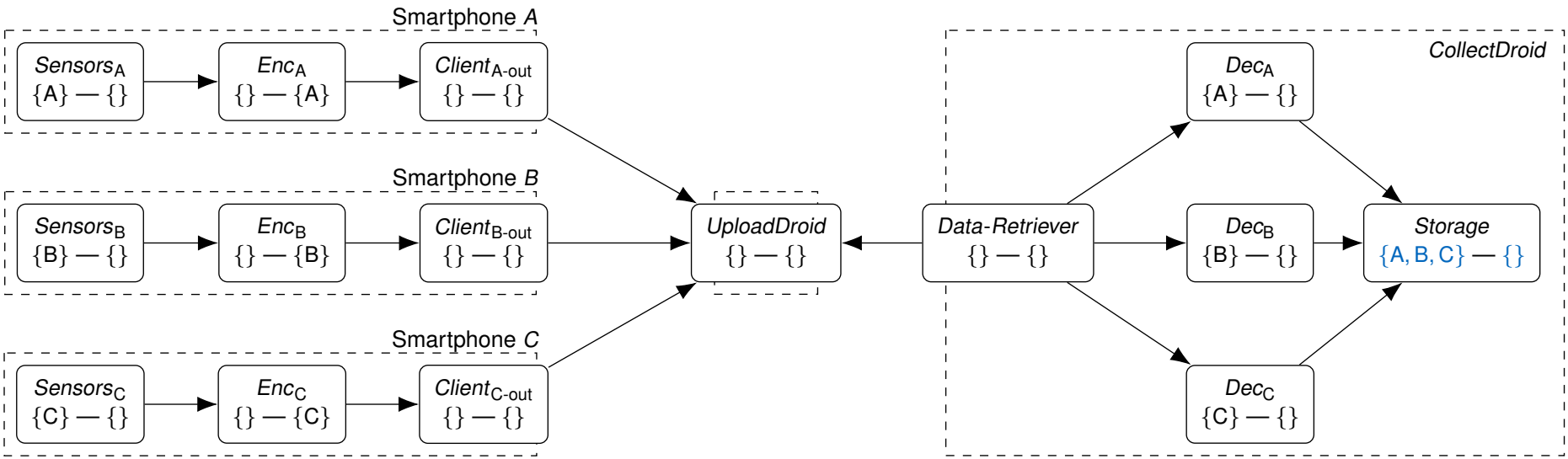

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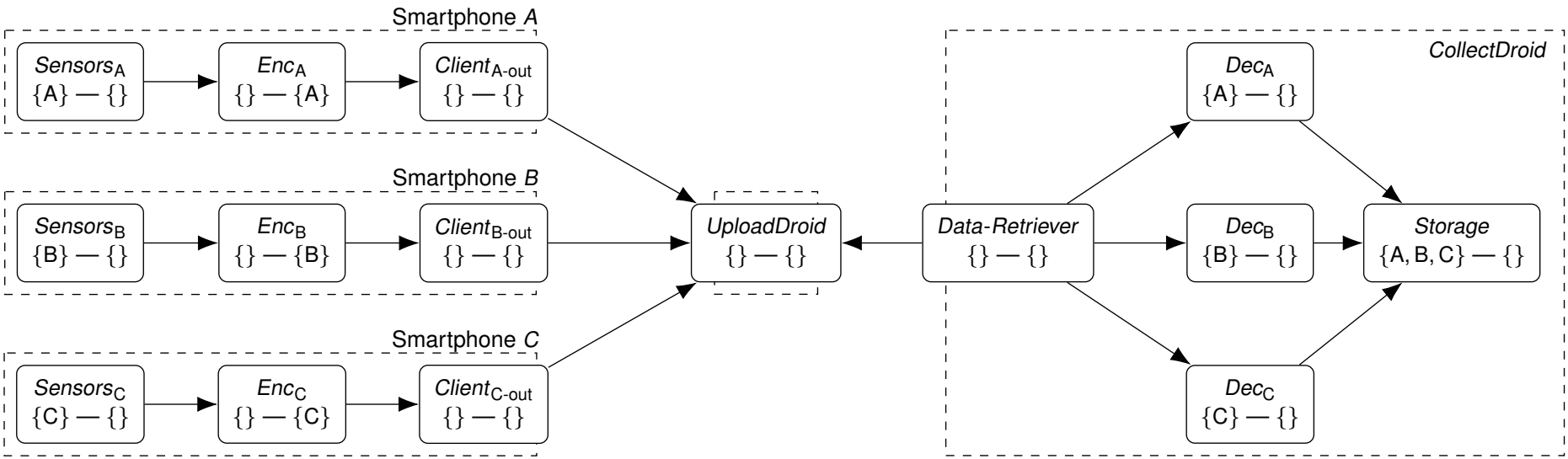

- Architecture valid according to taint analysis? ✓

MeasrDroid – Real-World Architecture Enforcement

- How is this architecture enforced?

MeasrDroid – Real-World Architecture Enforcement

- How is this architecture enforced?
- Central network firewall

Get a graph they said

diekmann@xps12: ~/git/net-network/configs_chair_for_Network_Architectures_and_Services

```
-A FORWARD -m state --state RELATED,ESTABLISHED,UNTRACKED -j ACCEPT
-A FORWARD -i eth1.110 -j NOTFROMHERE
-A FORWARD -i eth1.1024 -j NOTFROMHERE
-A FORWARD -m recent --update --seconds 60 --name DEFAULT --rsource -j LOG_RECENT_DROP2
-A FORWARD -p tcp -m state --state NEW -m tcp --dport 22 --tcp-flags FIN,SYN,RST,ACK SYN -
m recent --update --seconds 360 --hitcount 41 --name ratessh --rsource -j LOG_RECENT_DROP
-A FORWARD -s 127.0.0.0/8 -j LOG_DROP
-A FORWARD -s 131.159.14.221/32 -i eth1.1011 -j ACCEPT
-A FORWARD -s 131.159.15.252/32 -i eth1.152 -p udp -j ACCEPT
-A FORWARD -d 131.159.15.252/32 -o eth1.152 -p udp -m multiport --dports 4569,5000:65535 -
j ACCEPT
-A FORWARD -d 188.95.233.5/32 -i eth1.1011 -o eth1.97 -j ACCEPT
-A FORWARD -d 188.95.233.5/32 -o eth1.97 -p tcp -m tcp --sport 443 -j ACCEPT
-A FORWARD -s 131.159.15.247/32 -i eth1.152 -o eth1.110 -j ACCEPT
-A FORWARD -d 131.159.15.247/32 -i eth1.110 -o eth1.152 -j ACCEPT
-A FORWARD -s 131.159.15.248/32 -i eth1.152 -o eth1.110 -j ACCEPT
-A FORWARD -d 131.159.15.248/32 -i eth1.110 -o eth1.152 -j ACCEPT
-A FORWARD -d 131.159.14.26/32 -i eth1.110 -p tcp -m tcp --dport 22 -j ACCEPT
-A FORWARD -d 131.159.14.0/23 -i eth1.110 -p tcp -m state --state NEW -m tcp --dport 22 --
tcp-flags FIN,SYN,RST,ACK SYN -m recent --set --name ratessh --rsource
-A FORWARD -d 131.159.20.0/23 -i eth1.110 -p tcp -m state --state NEW -m tcp --dport 22 --
tcp-flags FIN,SYN,RST,ACK SYN -m recent --set --name ratessh --rsource
-A FORWARD -s 131.159.14.0/25 -i eth1.96 -j mac_96
-A FORWARD -i eth1.96 -j ranges_96
                                                              167,34        2%
```

It's easy they said

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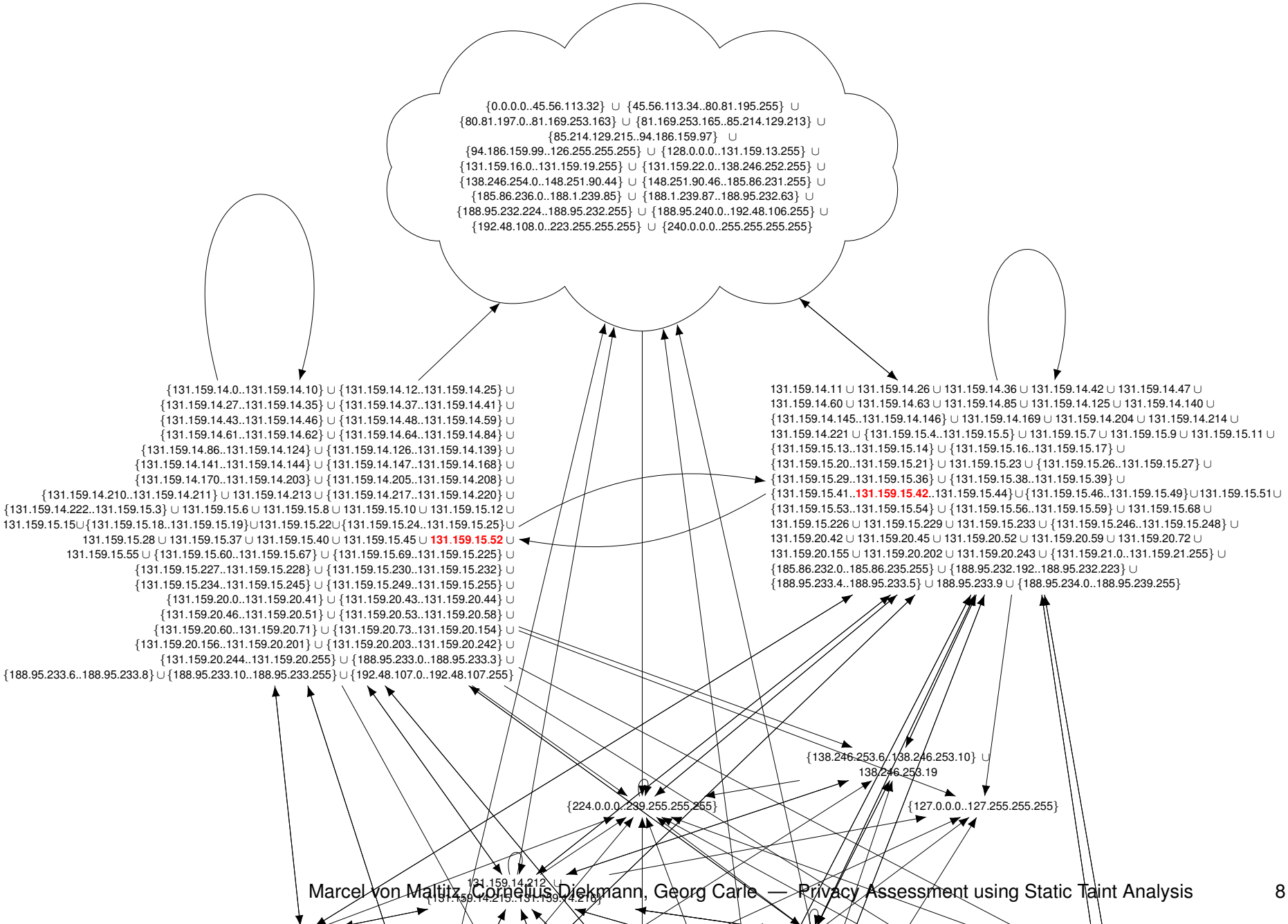

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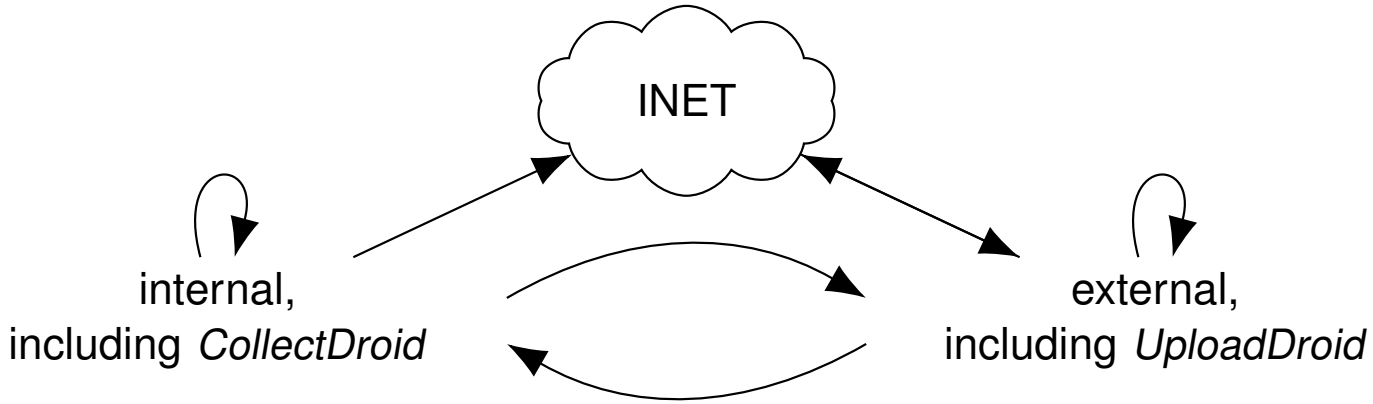

- Should be a graph isomorph to the architecture, disregarding
  - We cannot look inside the machines
  - All smartphones in INET

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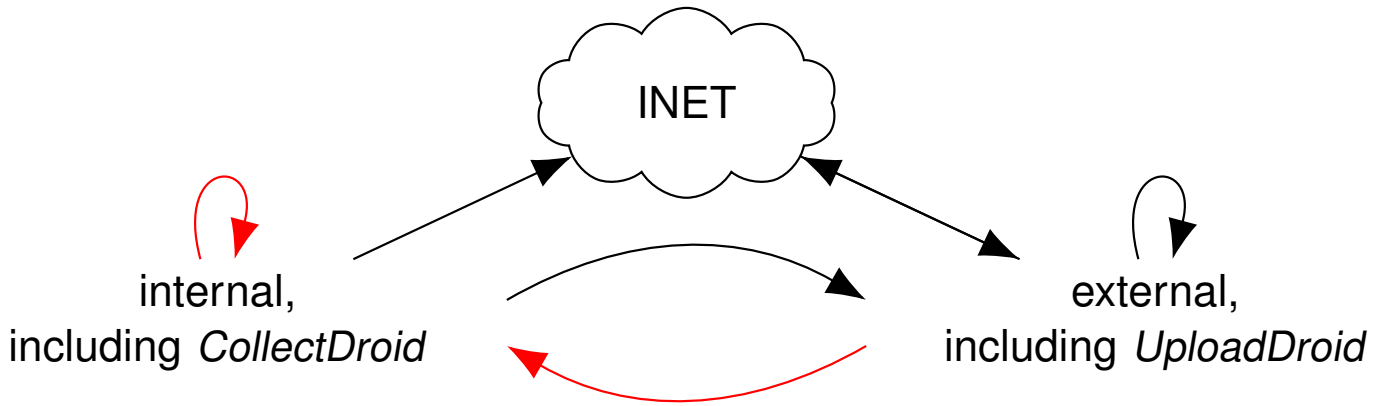

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- Actually, two major architecture violations (red arrows)
  - *UploadDroid* can attack *CollectDroid*
  - Any compromised internal host can attack *CollectDroid*

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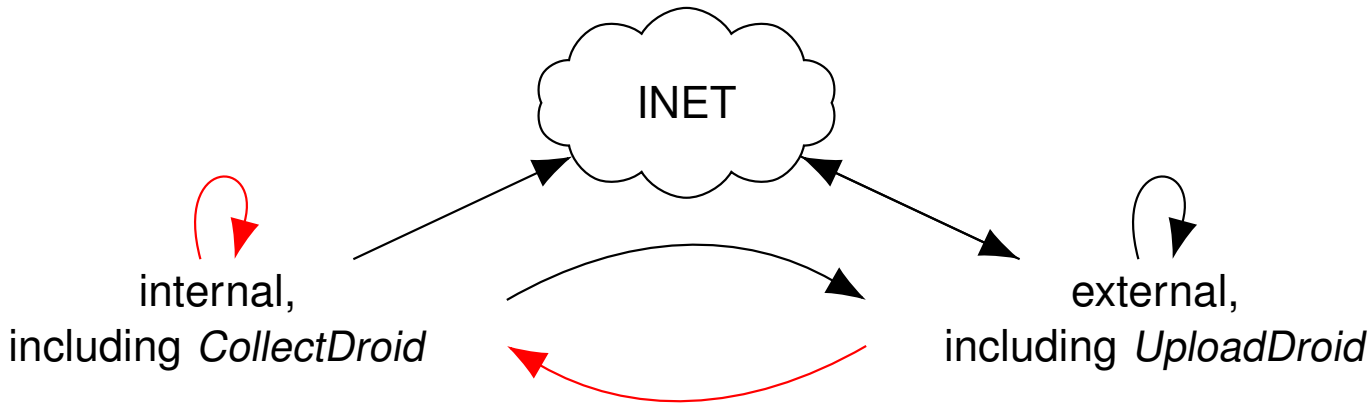

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- Actually, two major architecture violations (red arrows)
  - *UploadDroid* can attack *CollectDroid*
  - Any compromised internal host can attack *CollectDroid*
- Fixed by automated firewall generation feature of topoS

Conclusion

- Get your information flow as graph
- Add taint labels
- Do privacy analysis

Contributions

- Formalization of tainting, implemented in topoS
- Verified with Isabelle/HOL
- Two case studies

Tools

- C. Diekmann, A. Korsten, and G. Carle. Demonstrating topoS: Theorem-prover-based synthesis of secure network configurations. In *11th International Conference on Network and Service Management (CNSM)*, pages 366–371, Nov. 2015
- C. Diekmann, J. Michaelis, M. Haslbeck, and G. Carle. Verified iptables Firewall Analysis. In *IFIP Networking 2016*, Vienna, Austria, May 2016

- In the AFP & on github & `www.net.in.tum.de`

Backup Slides

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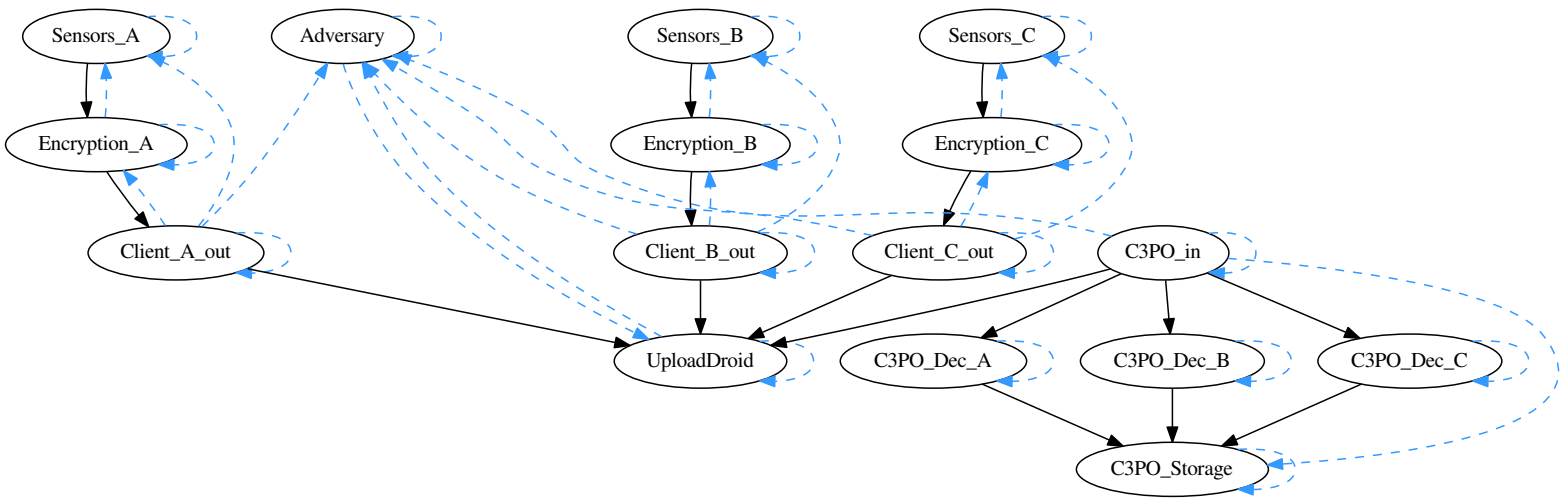
- How good is the architecture and requirement specification?



Screenshot of topoS

Backup Slides

Related Work: Dynamic Taint Analysis

- Taint analysis inspired by TaintDroid [9] and DroidDisintegrator [13]
- Dynamic runtime systems for individual Android devices/Apps
- Granularity: Android components

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