DDIFT: Decentralized Dynamic Information Flow Tracking for IoT Privacy and Security

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Warming Up


spyware
spam
phishing
trojan
data
security
virus
attack
malware
virus alert!
virus detected
25%

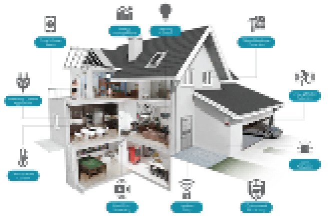
Overview

1. *Intro*: IoT era and DIFT
2. *DDIFT 1st step: Mobile phone running DIFT [fast timescale]*
3. *DDIFT 2nd step: Cloud running forensics [slow timescale]*
4. *DDIFT: Overview*
5. *Simulation* of DDIFT
6. *Conclusions*

1. Intro

2019: The dominance of IoT in human life is a reality

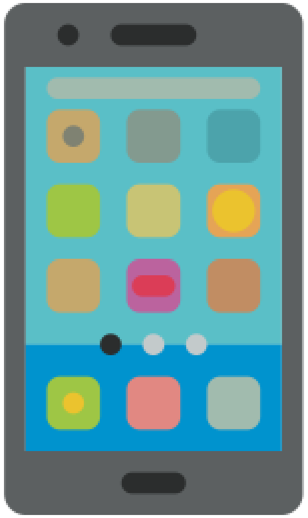
- Wearables
- Smart homes
- Healthcare
- Greening ecosystem



1. Intro

… usually *applications*, or *applets*, running at the mobile phone, is the interface to manage these devices

- Wearables *--> applet to upload to Doogle Dr. all new pics*
- Smart homes *--> open thermostat when I approach home*
- Healthcare *--> notify my doctor if my heart rate has improper impulses*
- Greening ecosystem *--> provide PV array analytics*



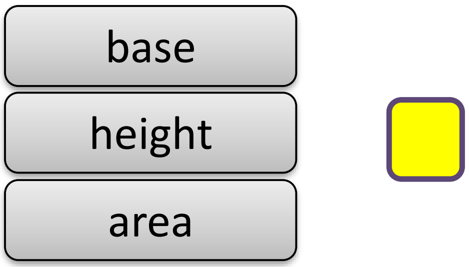
1. Intro

1. Intro: traditional DIFT

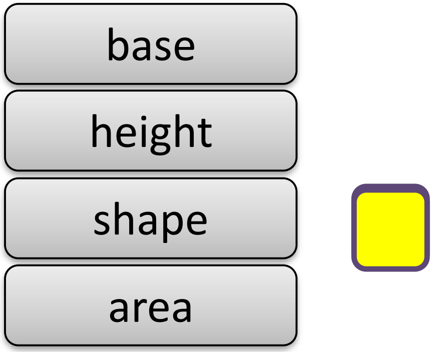
DIFT: works with 2 processes

- PROCESS A: **Tag insertion: insert tags to variables (or memory bytes)**
- PROCESS B: **Tag propagation: propagate tags during system execution**
  - *Direct Flow Propagations (DFP)*
  - *Indirect Flow Propagations (IFP)*

1. int base = 5; //the base of the triangle
2. int height = 4; //the base of the triangle
3. int area = base * height; //the area



1. int base = 5; //the base of the triangle
2. int height = 4; //the base of the triangle
3. int shape = “triangle”; //type of shape
4. (If shape == “triangle”)
5. area = base * height //the area



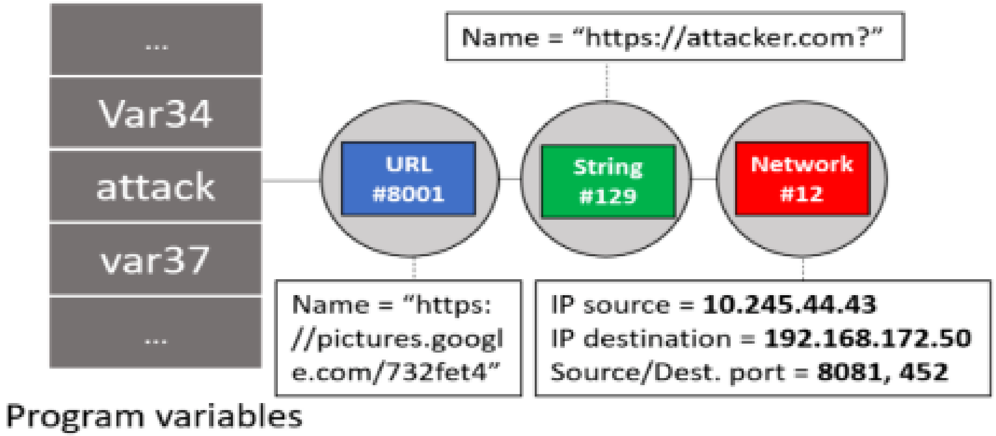
2. DDIFT Algorithm at device

What about DIFT in IoT?

2. Device: running DIFT at the app level

Challenges while applying DIFT in IoT [Tag Insertion]: :

1. **Different system activities add heterogeneous knowledge in the information flow and should add different level of security concerns**
   - **We consider tag differentiation (many colors), e.g., network, file, RV tags**
   - **Each variable has a list that accommodates up to N #of tags**
2. **Ability to reverse engineer back to the inputs**
   - **We keep provenance information (e.g., network tag coming from IP 13.2.3.5)**



2. Device: running DIFT at the app level

Challenges while applying DIFT in IoT [Tag Propagation]: (cont')

3. Limited (memory, battery resources).

- **Algorithm 1 (next slide): How to optimally allocate the limited resources to the vast #tags that attempt to propagate?**

4. Minimize false alarms that DIFT usually bring.

- **Algorithm 1 (next slide): Should all indirect flows be propagated?**

2. DDIFT Algorithm at device

Algorithm 1 Optimal resource allocation and indirect flow decisioning.

Input. $\mathcal{C}$: the objective metric we attempt to optimize.
Output. $\Delta(n_{t,i})$: drop or schedule the tag.

1: Define the objective metric we attempt to optimize based on the per-tag metric value $c_{t,i}$, the tag type weights λ, and the tag weights μ.

$$\mathcal{C} = \sum_t \lambda_t \sum_i \mu_{t,i} \cdot c(n_{t,i}) \tag{1}$$

2: In order to decide about the potential propagation of a tag, the DIFT system should consider which decision offers the best gain for $\mathcal{C}$. To that end, we differentiate $\mathcal{C}$ with respect to $n_{t,i}$ (number of copies of the i-th tag belonging at the t-th type), we discretize and obtain:

$$\begin{aligned}\Delta(\mathcal{C}) &= \sum_t \lambda_t \sum_i \mu_{t,i} \frac{\partial c(n_{t,i})}{\partial n_{t,i}} \Delta(n_{t,i}) = \\ &= \sum_t \sum_i U_{t,i} \Delta(n_{t,i}),\end{aligned} \tag{2}$$

where:

$$U_{t,i} = \lambda_t \cdot \mu_{t,i} \cdot \frac{\partial c_{t,i}}{\partial n_{t,i}} \text{ is the utility of tag \{t,i\}} \tag{3}$$

$$\Delta(n_{t,i}) = \begin{cases} -1, & \text{if the tag \{t,i\} is dropped} \\ 0, & \text{if no action for the tag \{t,i\} is taken} \\ +1, & \text{if the tag \{t,i\} is scheduled} \end{cases} \tag{4}$$

3: For *resource allocation*: the DIFT should (i) schedule (i.e., keep or propagate) the tags in the order of decreasing $U_{t,i}$, and (ii) drop (i.e., delete or not propagate) the tags with the lowest $U_{t,i}$ (i.e., to ensure that the tags "carrying" more information are prioritized).

4: For *indirect flow* propagation decisioning: the DIFT should propagate a tag if this tag has $U_{t,i} > 0$ (i.e., the indirect flow propagation brings information to the DIFT).

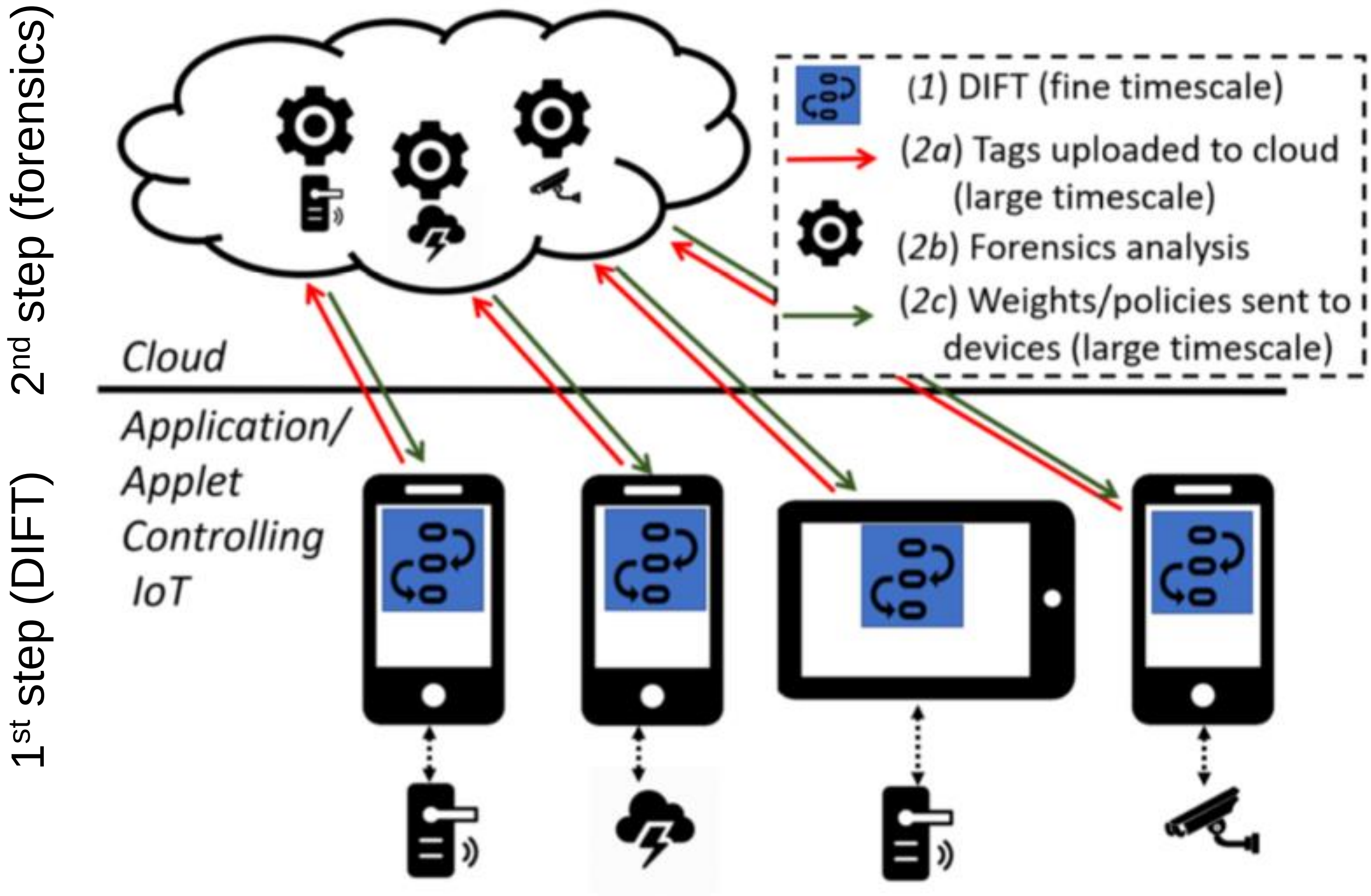
3. Cloud: running forensics

- Cloud performs heavy forensics analysis in a slow timescale, relying on a continuous analysis of a large volume of tags
- Cloud's main objective is to:
  - dictate the best values for the weighting parameters λ, μ, so e.g. the devices boost the important tags

$$\lambda = \lambda_{prev} + \zeta \cdot \sum_i \mu_{t,i} \cdot c(n_{t,i}),$$

  - develop privacy and security policies,
    - e.g. URL tag + String tag + netflow tag = URL Attack
    - learn a priory what strings, network connections etc. are suspicious

4. **DDIFT**: Decentralized Dynamic Information Flow Tracking



5. Simulations (N=5): traditional DIFT (propagate all IFs ☹)

1. na
2. nu
3. di
4. fo
5.
6.
7.
8. ex

exit

#89

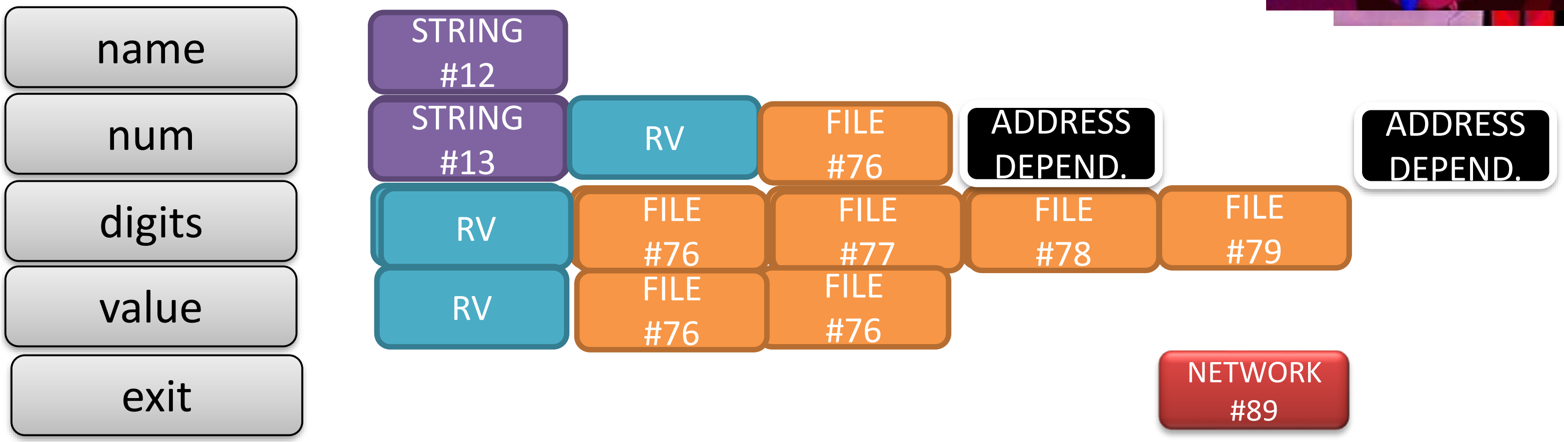
5. Simulations (N=5): traditional DIFT (propagate all IFs ☹)

All IFs propagated
=>
Over-tainting (+ memory pollution)

No one of the IF is propagated
=>
Under-tainting

Other over-tainting cases (when more space is available)
=>
Aggressively propagate tags

5. Simulations (N=5): DDIFT (α-fair utility) ☺



Simulated different provenance-list sizes scenarios:
Detection efficiency improvement 43%
Memory usage improvement 71%

6. Conclusions

- **DDIFT: dynamically tracks the information flow at the mobile device level, and adapts to the IoT challenges:**
  - ***Large #devices:*** Scalable scheme through the synergy of cloud (slow timescale) and device (fast timescale)
  - ***IoT limited resources:*** *optimally* prioritizing tags
  - **[open problem] Indirect Flow Propagation**: tackled with optimization theory
  - **Extendable to software and hardware**
  - **Able to design malware signatures through the tag confluwnces and further detect them**

Thank you!