FlowFence: Practical Data Protection for Emerging IoT Application Frameworks

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sed on authors' slides

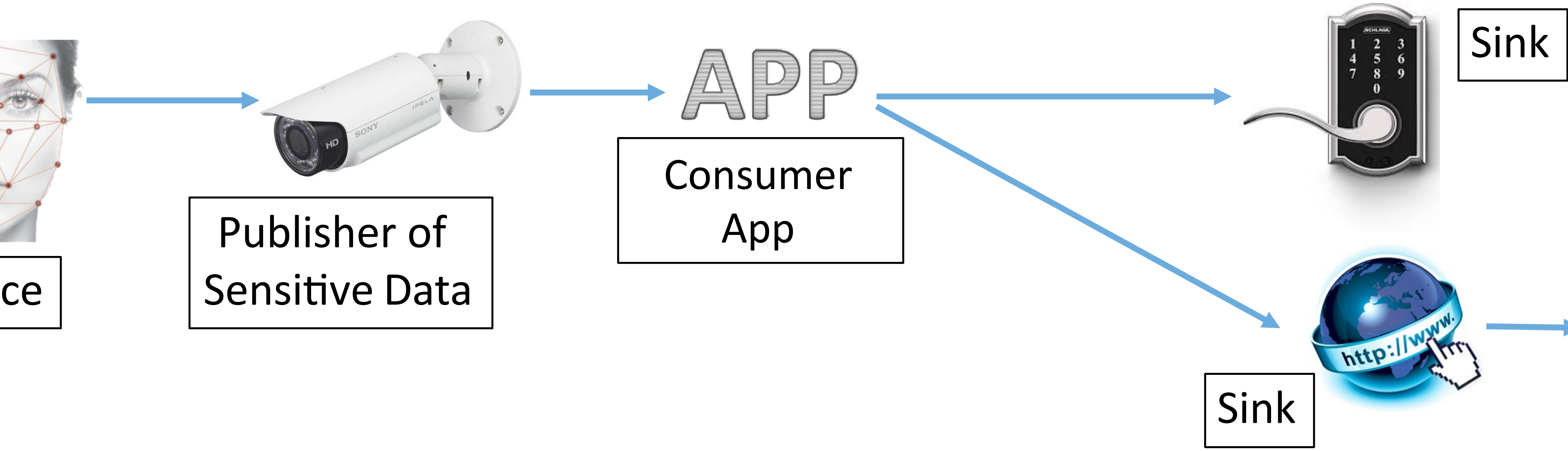
Presenter: Qi W

les/Quantified Self

Connected Healthcare

Smart Homes

Emerging IoT App Frameworks



nlock door if face is recognized
ome-owner can check activity
om Internet

- App needs to compute o
sensitive data to provide
useful service
- But has the potential to
leak data

Existing IoT frameworks have permission based access control

hings

Smart home API

[Smart Homes]

Google Fit API

[Wearables]

Android Sensor API

[Quantified Self]

e.g., capability.lockCodes in SmartThings (pincode
FITNESS_BODY_READ scope in Google Fit (heart r

- Permissions control what data an app can access
- Permissions do not control how apps use data, once they have access

FlowFence

Flow-control is a first-class primitive

based flow control
- mponent-level information tracking
- w enforcement through label policies

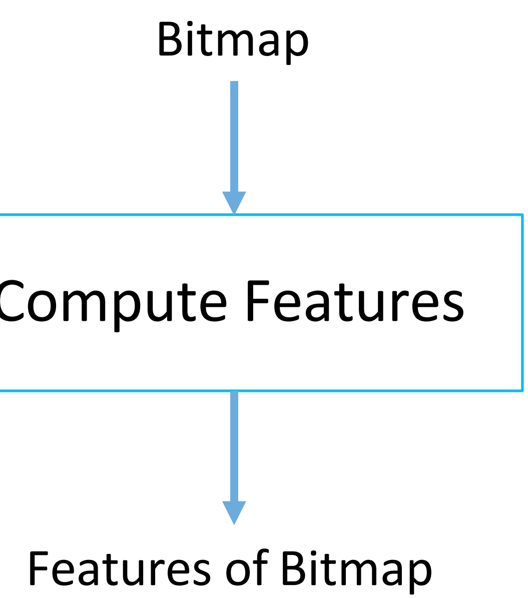
+

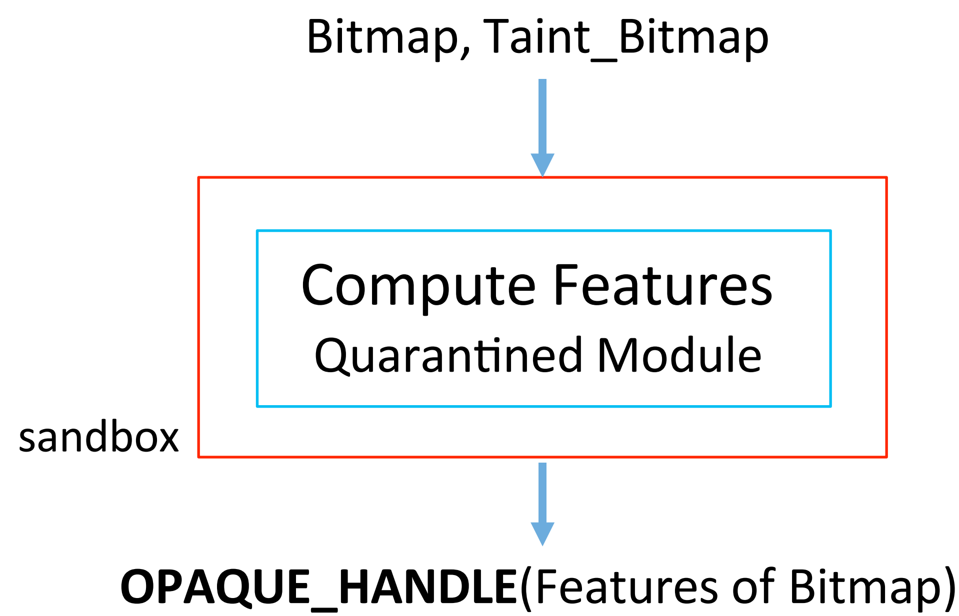
Language-based flow control
- Restructure apps to obey flow
- Developer declares flows

=

FlowFence
- Support of diverse publishers and consumers of data, with publisher and consumer flow policies
- Allows use of existing languages, tools, and OSes

Quarantined Modules and Opaque Handles

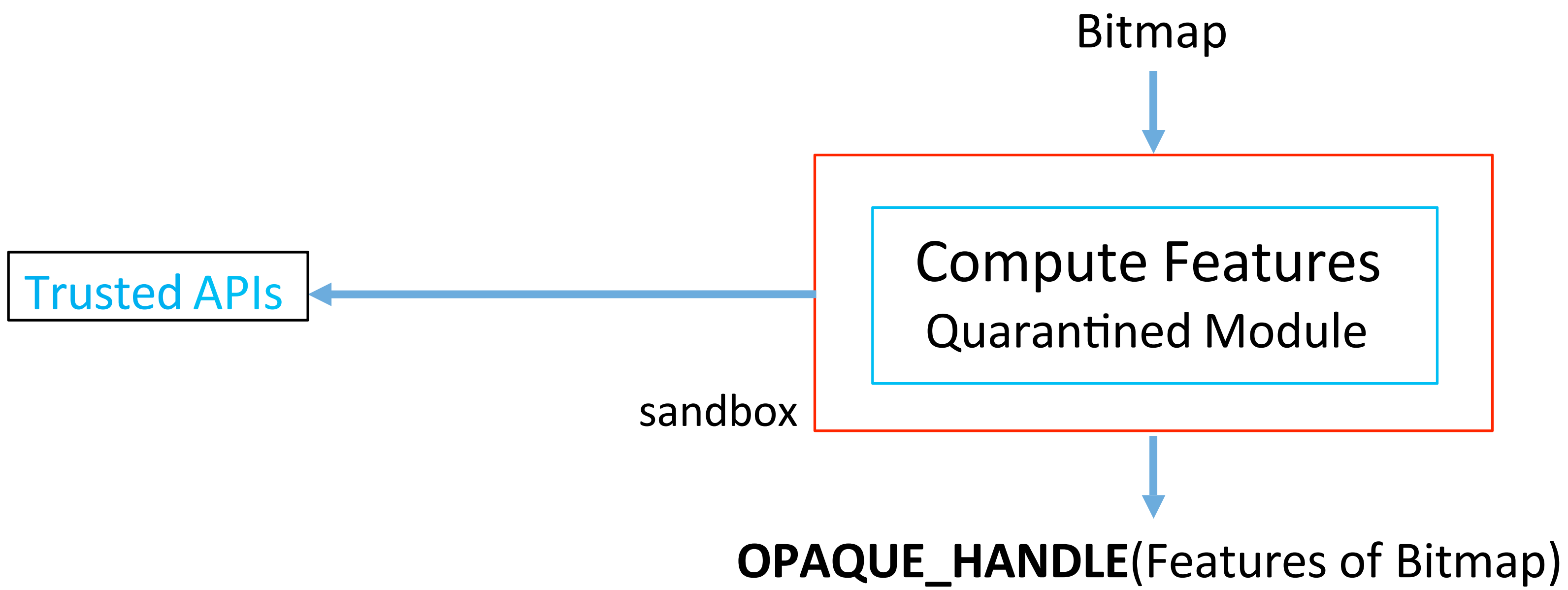




e computation runs with
e rights to access sensitive
tmap data

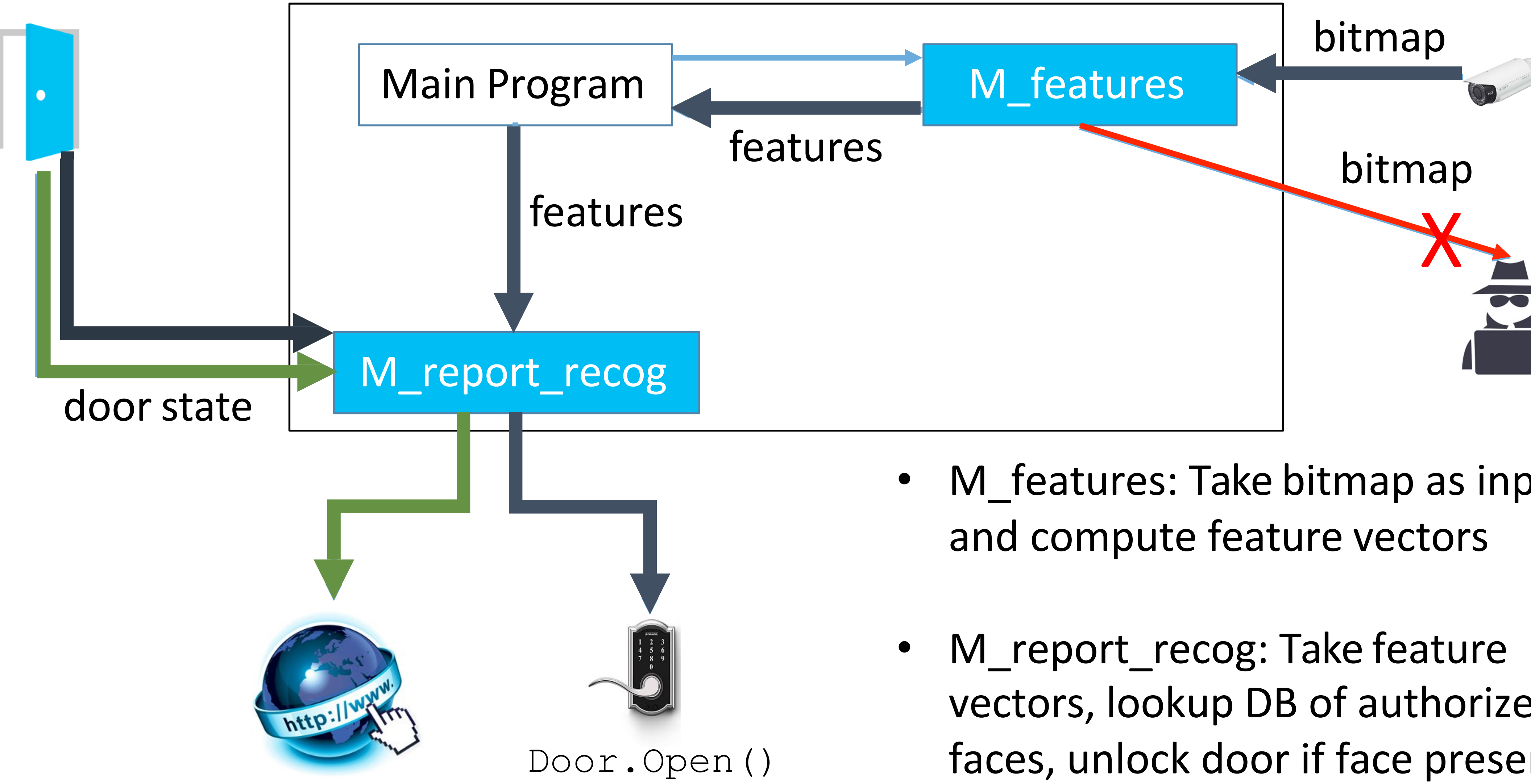
- Submit a computation that runs in a sand
- All sensitive data is available only in sand

Quarantined Modules and Opaque Handles



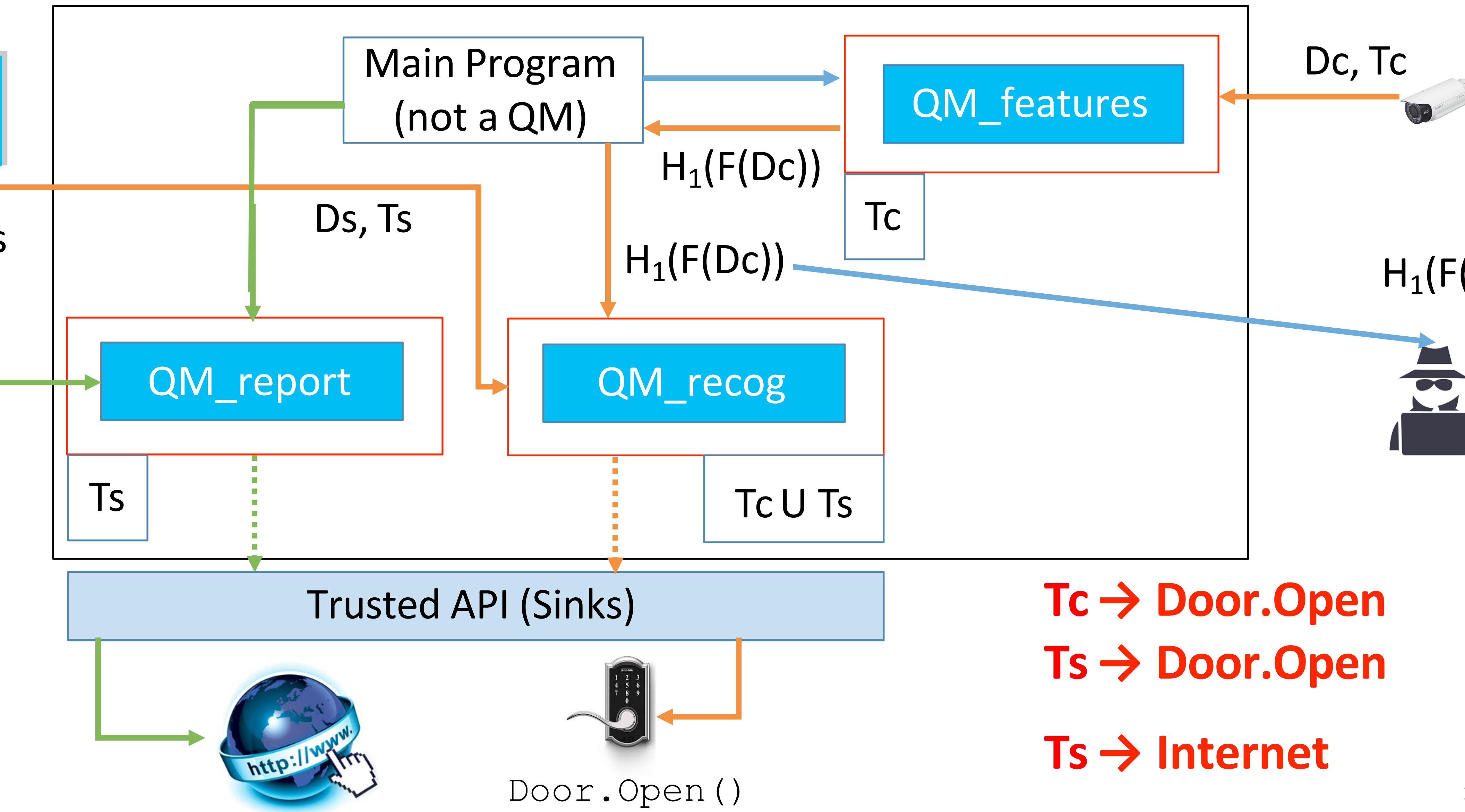
Quarantined Modules can also access FlowFence-provided Trusted APIs
Trusted APIs check the taint labels of the caller against a flow policy

Face Recognition App Example



- M_features: Take bitmap as inp
and compute feature vectors
- M_report_recog: Take feature
vectors, lookup DB of authorize
faces, unlock door if face prese
Report door state

FlowFence – Refactored App



Taint Labels and Flow Policies

H_1	{T1, T2, …}	F(D1)

App_ID	Label_Name
om.camera.publisher	Taint_Camera

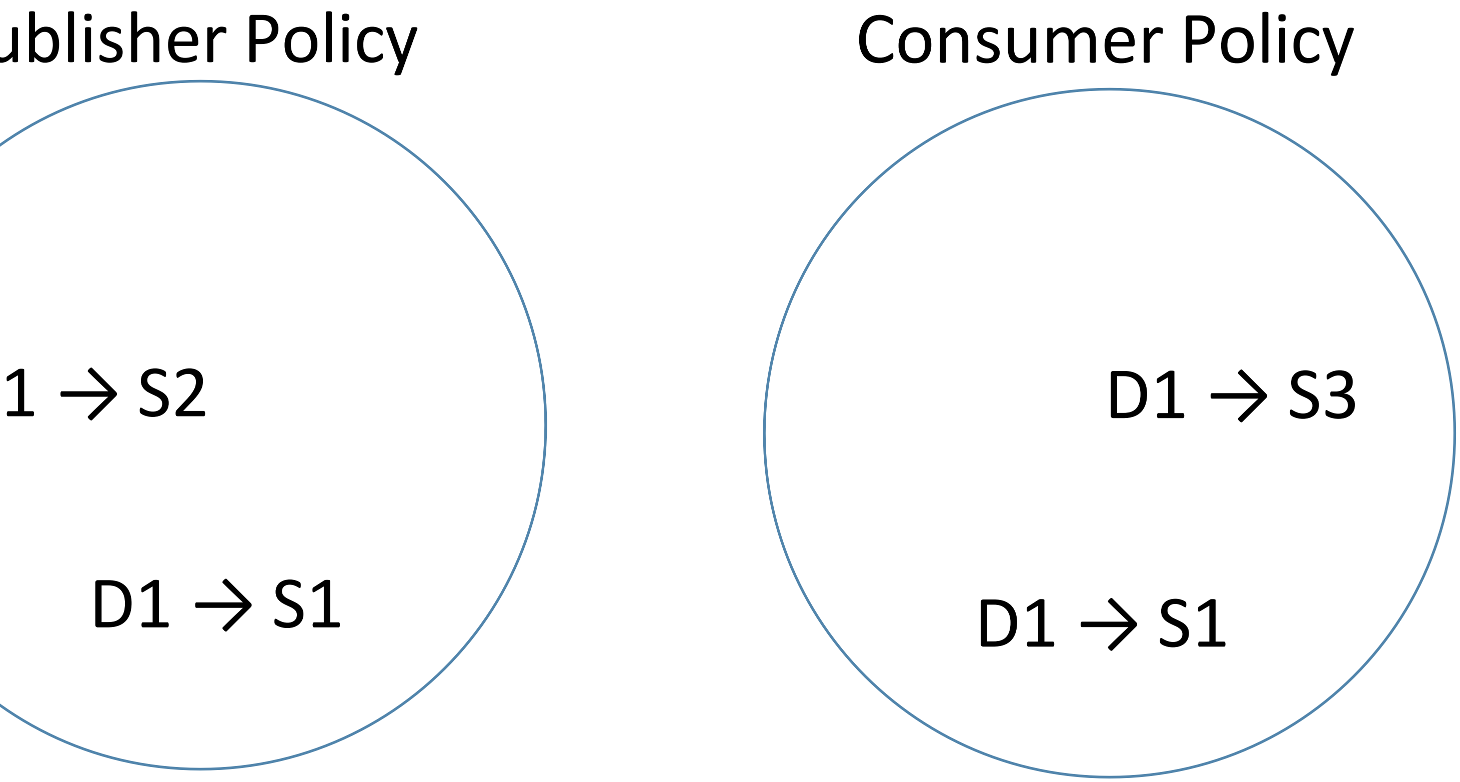
Example Policy

{
  Taint_Camera → UI,
  Taint_HeartR → Internet
}

App_ID – unique application identifier on the underlying OS

Label_Name – well-known string that identifies the type of da

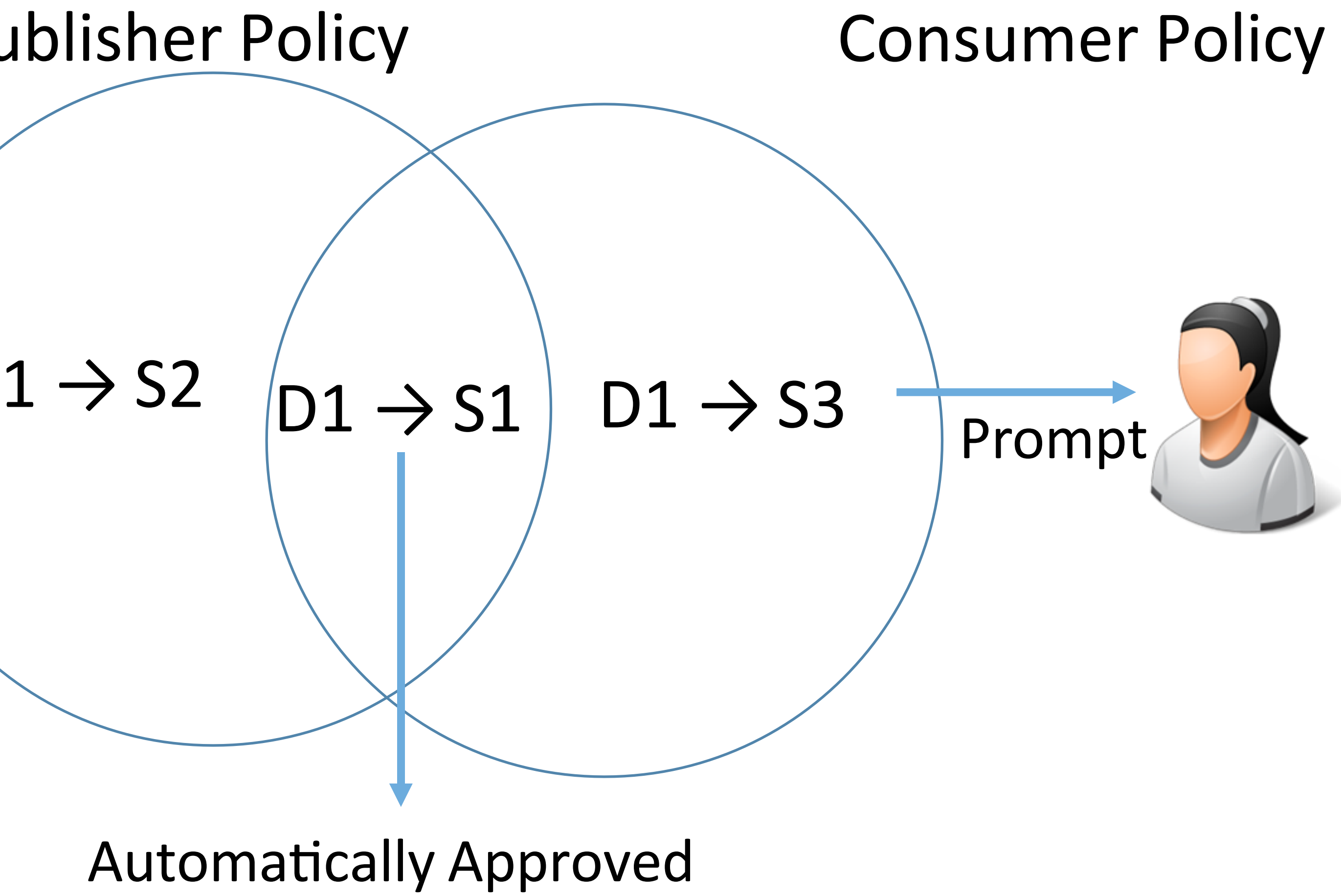
Publisher and Consumer Flow Policies



{ Publisher;
Taint_Camera → UI
}

{ Consumer;
Taint_Camera → Door.C
Taint_DoorState → Doo
Taint_DoorState → Inte
}

Publisher and Consumer Flow Policies



{ Publisher;
  Taint_Camera → UI
}

{ Consumer;
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  Taint_DoorState → Doo
  Taint_DoorState → Inte
}

Data Sharing Mechanisms in Current IoT Frameworks

Smart home API

[Smart Homes]

Google Fit API

[Wearables]

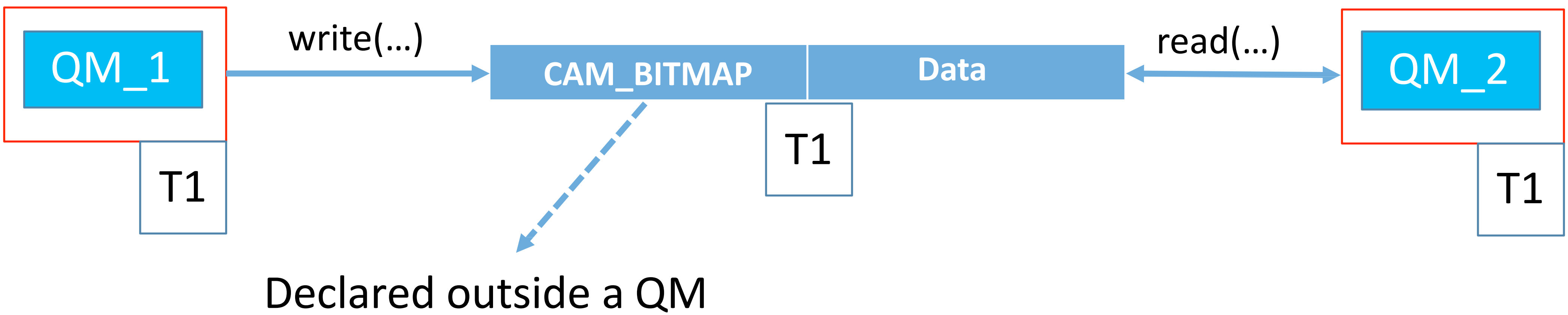
Android Sensor API

[Quantified Self]

- Polling Interface
  - App checks for new data
- Callback Interface
  - App is called when new data available
- Device Independence
  - E.g., many types of heart rate sensors produce “heart beat” data
  - Consumers should only need to specify “what” data they want, without specifying “how”

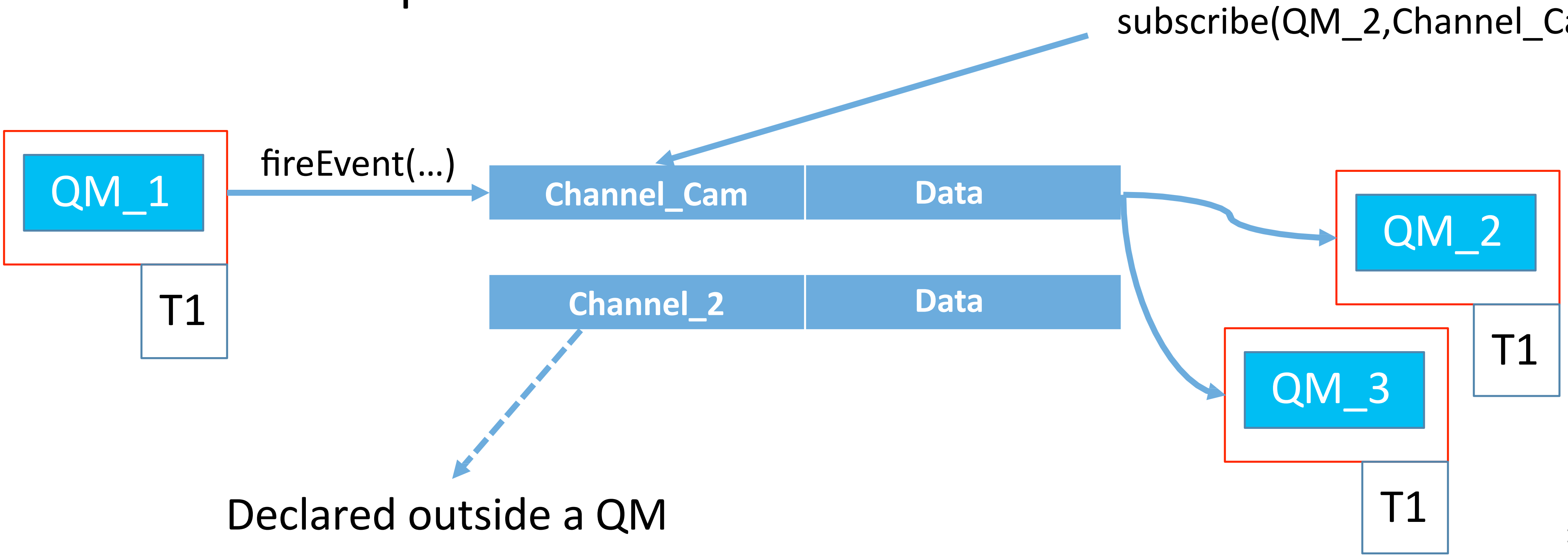
Key-Value Store –
Polling Interface/Device Independence

- ach app gets a single Key-Value Store
- n app can only write to its own Key-Value Store
- pps can read from any Key-Value Store
- eys are public information because consumers need to know about the



Event Channels –
Callback Interface/Device Independence

Apps can declare statically in code, their intended channels
Only the owner of a channel can fire an event
Channel name is public information



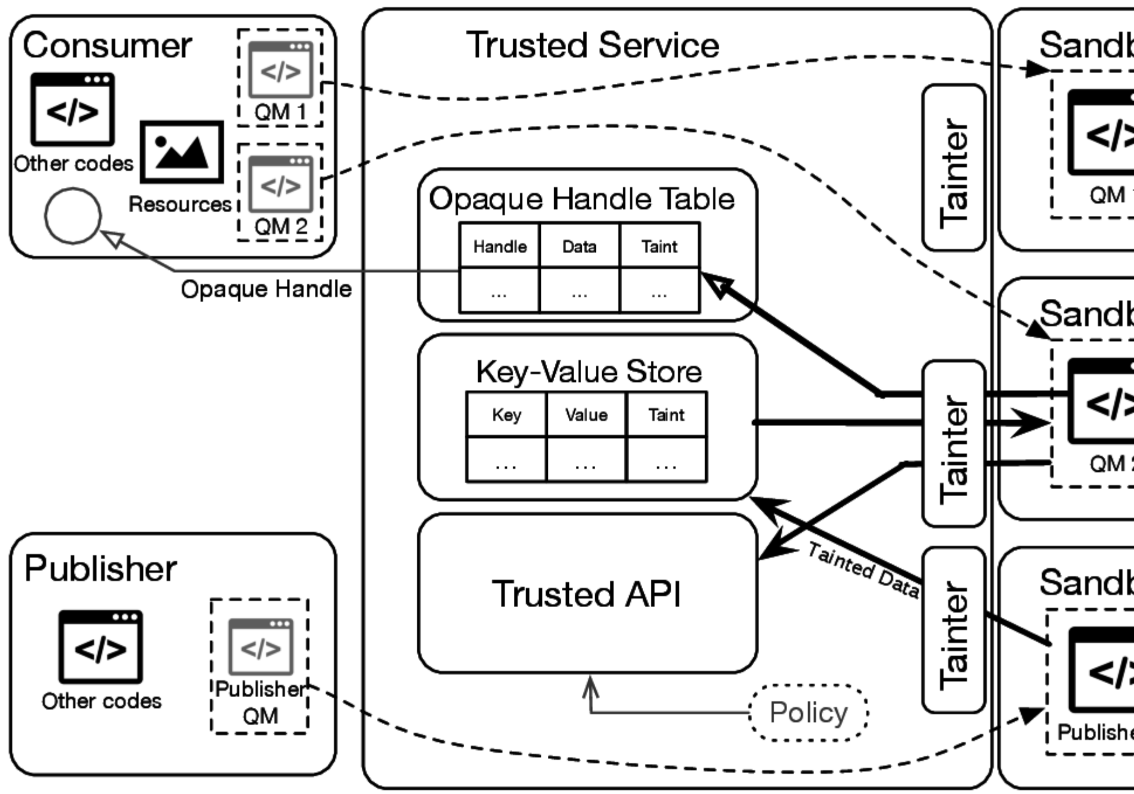
FlowFence Implementation

IoT Architectures

- Cloud
- Hub

”

- isolatedProcess = true for sandboxe
- Supports native code



Evaluation Overview

What is the overhead on a micro-level in terms of computation and memory?

Per-Sandbox Memory Overhead	2.7 MB
QM Call Latency	92 ms
Data Transfer b/w into Sandbox	31.5 MB/s

Comparable to IoT device ops over
area-network, e.g., Nest, SmartThi

Nest cam peak bandwidth is 1.2 M

Can FlowFence support real IoT apps securely?

Ported 3 Existing IoT Apps: SmartLights, FaceDoor, HeartRateMonitor	Required adding less than 140 lines per app; FlowFence isolates flows

What is the impact of FlowFence on macro-performance?

FaceDoor Recognition Latency	5% average increase
HeartRateMonitor Throughput	0.2 fps reduction on average
SmartLights end-to-end latency	+110 ms on average

Porting IoT Apps to FlowFence

App	Data Security Risk	Original LoC	FlowFence LoC	Flow Request
SmartLights	Can leak location information	118	193	Loc → Switch
FaceDoor	Can leak images of people	322	456	Cam → Lock, Doorstate → Lock Doorstate → Net
HeartRateMon	Can leak images and heart rate	257	346	Cam → UI

artLights, FaceDoor – 2 days of porting effort each, HeartMon – 1 day of porting ef

Macro-performance of Ported Apps

aceDoor Enroll Latency

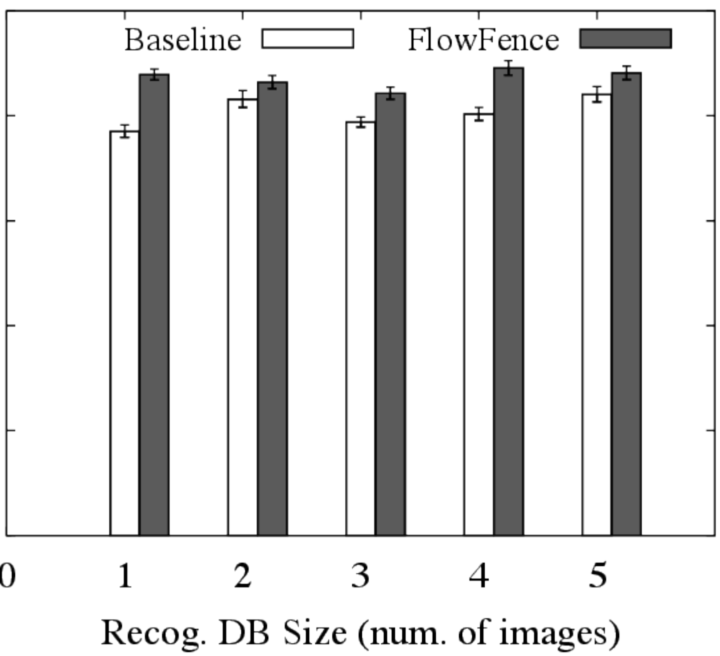
aseline	811 ms (SD = 37.1)
wFence	937 ms (SD = 60.4)

SmartLights End-To-End Latency

Baseline	160 ms (SD = 69.9)
FlowFence	270 ms (SD = 96.1)

eDoor Recognition Latency

(612x816 pixels)



HeartRateMon Throughput

Throughput w/o Image Processing	23.0 (SD=0.7) fps	22.9 (SD=0.
Throughput w/ Image Processing	22.9 (SD=0.7) fps	22.7 (SD=0.

Summary

merging IoT App Frameworks only support permission-based access contro
lalicious apps can steal sensitive data easily

owFence explicitly embeds control and data flows within app structure;
evelopers must split their apps into:

- Set of communicating Quarantined Modules with the unit of communication being Opaque Handles – taint tracked, opaque refs to data
- Non-sensitive code that orchestrates QM execution

owFence supports publisher and consumer flow policies that enable building
ecure IoT apps

/e ported 3 existing IoT apps in 5 days; Each app required adding < 140 LoC

lacro-performance tests on ported apps indicate FlowFence overhead is
easonable: e.g., 4.9% latency overhead to recog. a face & unlock a door

Discussion

- Vhat's the limitation of FlowFence?
- low is the usability of FlowFence to developers and users?
- low to improve FlowFence?
- Vhat makes protecting IoT challenging?
- s FlowFence able to mitigate the attacks we discussed in last class?

Instruction-Level Flow Analysis Techniques

Dynamic Taint Tracking

ne granularity
o developer effort
gh computational overhead
ay need special h/w for acceleration
plicit flows can leak information
nited OS/Language flexibility

IoT devices (and hubs) have
constrained hardware

OS and Language Diversity;
[Supports Rapid Developme

Static Taint Tracking

ne granularity
o developer effort
plicit flows can leak information
C and async. code can leak information

Fundamental Trigger-Action
Nature of IoT apps = Lots of
async. code