Preventing Accidental Data Disclosure in Modern Operating Systems

CCS `13

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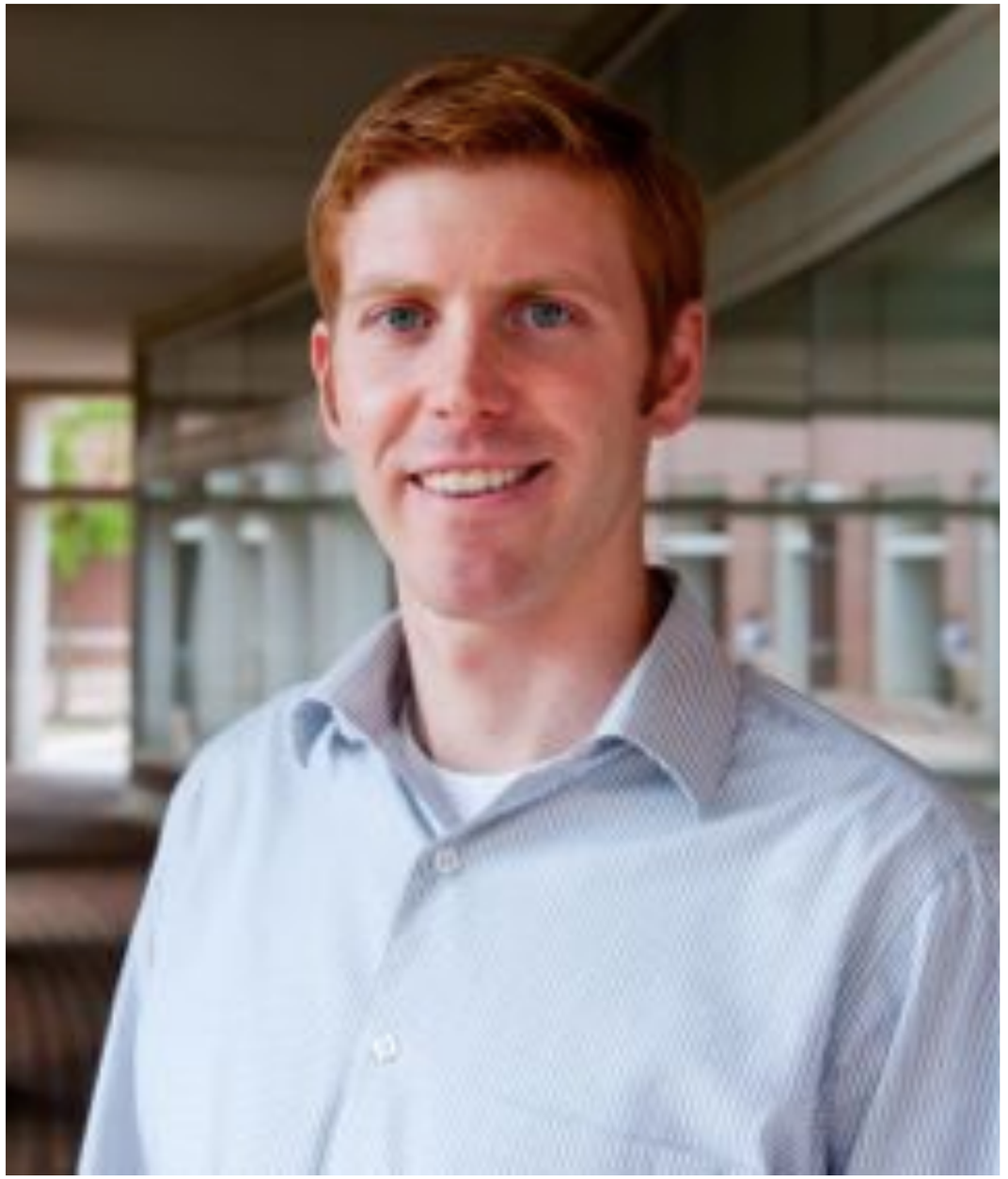

Background

- Modern OSes run each application as a unique security principal.
- Navigates through a series of screens.
- OSes provide modular apps.

Example—Problem

- Data intermediary problem:
  - share sensitive data with other app
  - result from user choices in selecting apps
  - Most apparent in modern OSes

Example—Signing a Doc

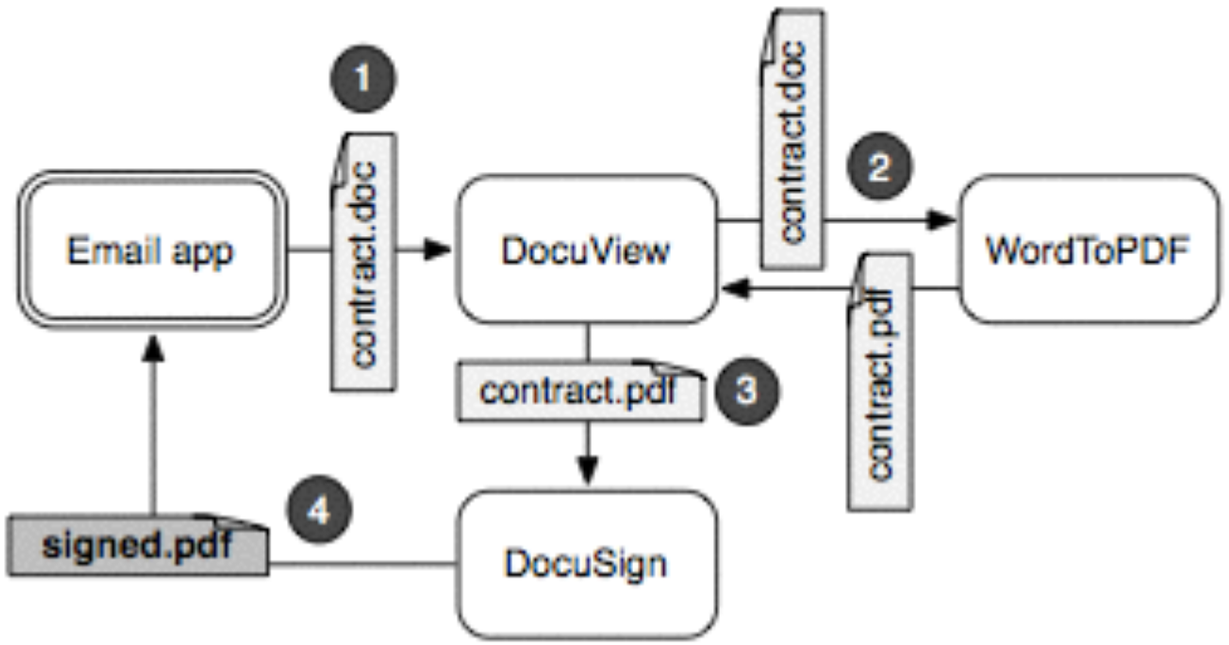

Figure 1: Document signing use case with four apps. A confidential contract received via Email is 1) read in a viewer, 2) converted to PDF, 3) embedded with a written signature, and 4) Emailed back to the sender.

Example—Problem

- Accidental data disclosure:
  - share data with wrong app
  - poorly programmed app
- No malicious data disclosure

Example—Signing a Doc

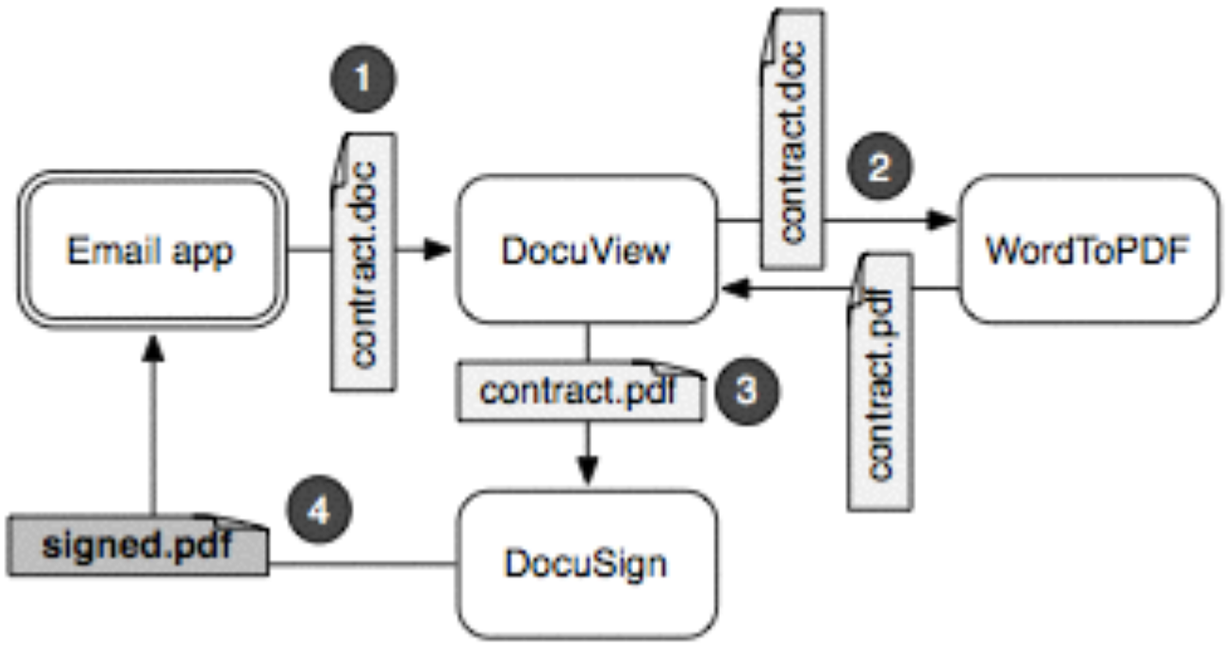

Figure 1: Document signing use case with four apps. A confidential contract received via Email is 1) read in a viewer, 2) converted to PDF, 3) embedded with a written signature, and 4) Emailed back to the sender.

Aquifer

Aquifer

- designed to protect large, application-specific, user data objects
- developer specify secrecy restrictions
- all apps participating in a user interface workflow

Android background

- Four component type: activity, service, content provider, and broadcast receiver
- Each UI is defined by a activity
- Other components run in background
- binder framework provides process control and IPC

User Interface workflow

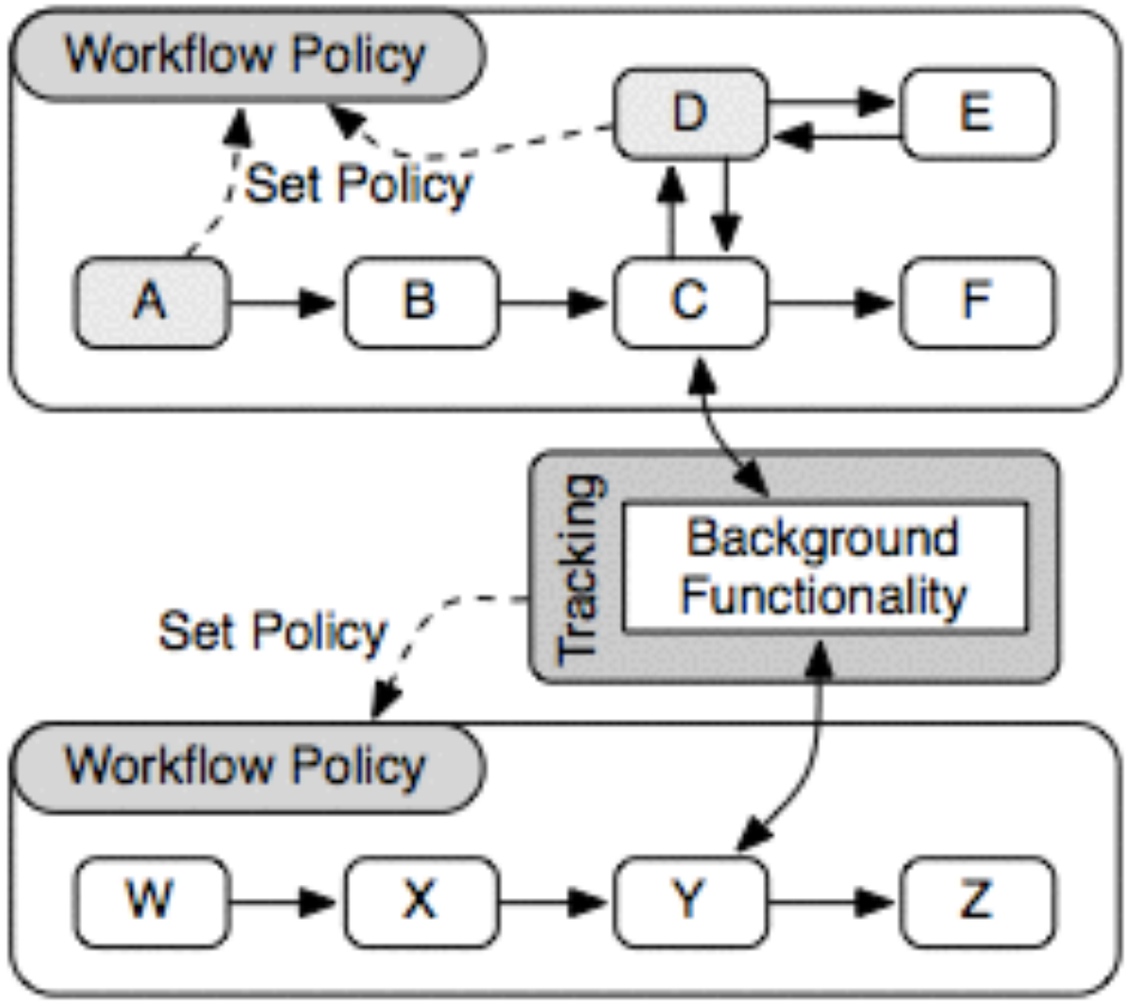

Figure 2: Aquifer policy abstraction

Architecture

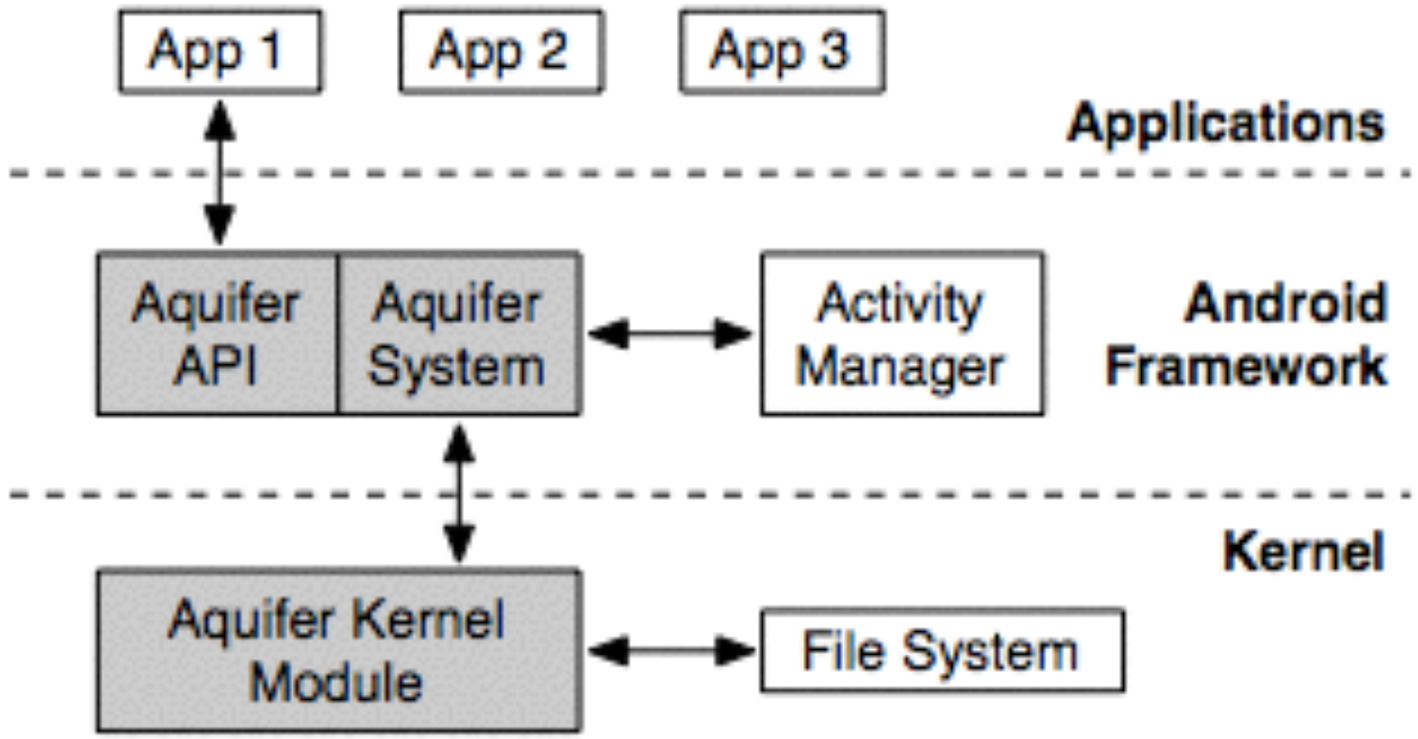

Figure 3: Aquifer architecture for Android

Principle

- Decentralized policy specification
- Developers & Users define policy
- Compatibility with legacy applications (default policy)
- Minimizing policy violations (filter)
- Compatibility with background functionality (file description)

Aquifer Policy

- Policy types:
  - **Export Restrictions**
  - **Required Restrictions**
  - **Filters**

Aquifer Policy

Definition 1 (Export list)**.** An export list E is a set of applications that may access the network while participating in the UI workflow.

Definition 2 (Required list)**.** A required list R is a set of applications that all must have been present on the UI workflow at sometime in the past for any application on the UI workflow to access the network.

Definition 3 (Workflow filter)**.** A workflow filter F is a set of tuples $\{(s_1, T_1), \ldots, (s_n, T_n)\}$, each containing an action string s_i and a set of targets T_i. If the normal resolution of an intent message sent to action string s_i is a set of apps N, then the resulting allowed target applications is $N \cap T_i$.

Definition 4 (Workflow label)**.** A workflow label L is an expression $L = \{O_1 : (E_1, R_1, F_1); \ldots; O_n : (E_n, R_n, F_n)\}$, where O_i is an owner (application) and E_i, R_i, and F_i are an export list, required list, and workflow filter, respectively, specified by O_i.

Definition 5 (Effective export list)**.** For a workflow label L, the effective export list $E_e = \bigcap exports(L, O), \forall O \in owners(L)$.

Definition 6 (Effective required list)**.** For a workflow label L, the effective required list $R_e = \bigcup requires(L, O), \forall O \in owners(L)$.

Definition 7 (Effective workflow filter)**.** For a workflow label L, the effective workflow filter F_e is the set of tuples containing action string and corresponding target application set created by taking the union of all action strings and the intersection of the targets for those action strings. More precisely, $F_e = \{(s_i, T_i) \mid s_i \in \bigcup actions(F)$ and $T_i = \bigcap targets(F, s_i), \forall F \in filters(L, O), \forall O \in owners(L)\}$.

Definition 8 (Label join $\sqcup$)**.** For workflow labels L_1 and L_2, the join $L = L_1 \sqcup L_2$ is a new label ensuring the following for all owners O:

$$
\begin{aligned}
owners(L) &= owners(L_1) \cup owners(L_2) \\
exports(L, O) &= exports(L_1, O) \cap exports(L_2, O) \\
requires(L, O) &= requires(L_1, O) \cup requires(L_2, O) \\
filters(L, O) &= \{(s_i, T_i) | s_i \in actions(F_1) \cup actions(F_2), \\
&\qquad T_i = targets(s_i, F_1) \cap targets(s_i, F_2), \\
&\qquad \text{where } F_1 = filters(L_1, O), \\
&\qquad F_2 = filters(L_2, O)\}
\end{aligned}
$$

Aquifer System

- Identifying the Workflow:
    - a list of applications the workflow has visited
        - a list of metadata for currently “running”UI screens
- Policy Administration
- Removing Unrelated Policy

Aquifer System

- Controlling the network access of the UI screen

- Enable network if and only if:

$$(E_e = \emptyset \vee app(p) \in E_e) \wedge (\forall r \in R_e, r \in W_V)$$

Background Functionality

- Accessing a Daemon:
  - Fine-grained tracking (taintDroid and CleanOS)
    - leveraging Linux's file_permission LSM hook
- Accession a File:
  - save label with file
  - the hook notifies the Aquifer Service

Evaluation

Table 1: Application Survey Results

Characteristic	Number of Apps
Data sources	85 (17%)
Data intermediaries	140 (28%)
Value from Export Policy	70 (14%)
Value from Regulate Policy	78 (15.6%)

based on 500 apps from Google Play Store

Evaluation

Table 2: Microbenchmark Results

Benchmark	Android	Aquifer	Overhead
App load	188.49±5.36 ms	192.07±6.30 ms	1.9%
App filter	194.12±7.91 ms	195.22±7.52 ms	0.55%
Net access	108.60±6.48 ms	109.64±6.31 ms	0.53%
Policy change	-	1.98±1.27 ms	-
File Read (1MB)	4.76±0.09 ms	5.23±0.22 ms	9.87%
File Write (1MB)	23.89±0.45 ms	25.44±0.86 ms	6.49%

Case-Study

- K-9 Mail and PDFView(sending to a server; saving file and sending it later)

- modified K-9 to be Aquifer-aware. Policy:

$$E = \{\texttt{K9EMail}\}$$
$$R = \{\}$$
$$F = \{(\texttt{ACTION\_SEND}, \{\texttt{K9EMail}\})\}$$

- re-performed and PDFView can not access to the network

Discussion

- lead to usability failures:
  - cause by developer
  - due to Aquifer policy result

Conclusion

- presented the Aquifer security framework that assigns host export restrictions on all data accessed as part of a UI workflow.

- key insight was that when applications in modern operating systems share data, it is part of a larger workflow to perform a user task.

- enable applications to sensibly retain control of their data after it has been shared as part of the user’s tasks.