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Proteus: A Practical Framework for Privacy-Preserving Device Logs

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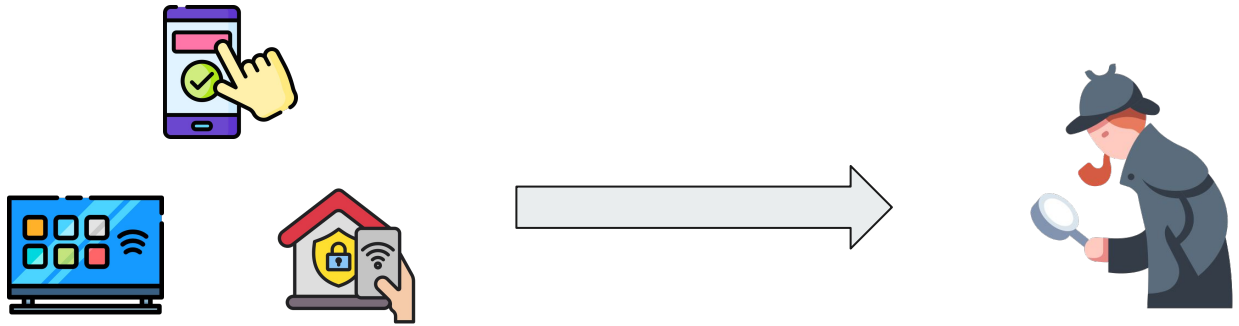
Mobile devices are now audit-critical systems.

- Considered a critical security endpoint that require constant monitoring.
- Audit logging is essential for post-hoc security measures.
- Regulatory frameworks require audit trails and forensic visibility from end devices.



Problem : PII Leakage in Device Logs.

PII type	Devices				Manufacturers		Android Version					
	Initial Log	Final Log	Detected	Prevalence	Detected	Prevalence	≤ 7	8	9	10	11	12
Android ID	50	82	92	8%	26 of 45	58%	29%	19%	11%	12%	3%	0%
Bluetooth MAC	85	123	136	11%	27 of 45	60%	44%	14%	21%	9%	10%	6%
Bluetooth Name	724	782	836	69%	40 of 45	89%	81%	55%	82%	64%	74%	61%
Bluetooth Scan MAC	5	26	26	2%	10 of 45	22%	13%	0%	1%	1%	1%	6%
Bluetooth Scan SSID	13	26	26	2%	7 of 45	16%	9%	3%	4%	1%	1%	3%
Coarse Location	246	245	292	24%	14 of 45	31%	15%	14%	25%	23%	19%	42%
Email Address	192	180	198	16%	4 of 45	9%	57%	23%	16%	11%	28%	0%
Fine Location	224	231	272	22%	14 of 45	31%	15%	12%	25%	20%	18%	40%
IMEI	14	10	16	6%	9 of 30	30%	27%	5%	4%	-	-	-
Phone Number	11	12	14	3%	4 of 40	10%	5%	4%	3%	3%	-	-
Serial Number	43	40	49	4%	12 of 45	27%	26%	5%	4%	1%	4%	3%
WiFi Randomized MAC	242	532	539	78%	19 of 20	95%	-	-	-	-	71%	89%
WiFi Router MAC	500	795	814	67%	35 of 45	78%	54%	38%	55%	44%	76%	94%
WiFi Router SSID	597	808	829	68%	35 of 45	78%	60%	63%	61%	51%	75%	83%
WiFi Scan MAC	89	167	175	14%	19 of 45	42%	22%	15%	24%	7%	12%	23%
WiFi Scan SSID	364	462	475	39%	24 of 45	53%	26%	37%	27%	26%	37%	69%
Any PII Detected	998	1108	1142	94%	45 of 45	100%	97%	91%	95%	88%	95%	100%

PII leakage in device logs is prevalent across manufacturers, devices, and OS.

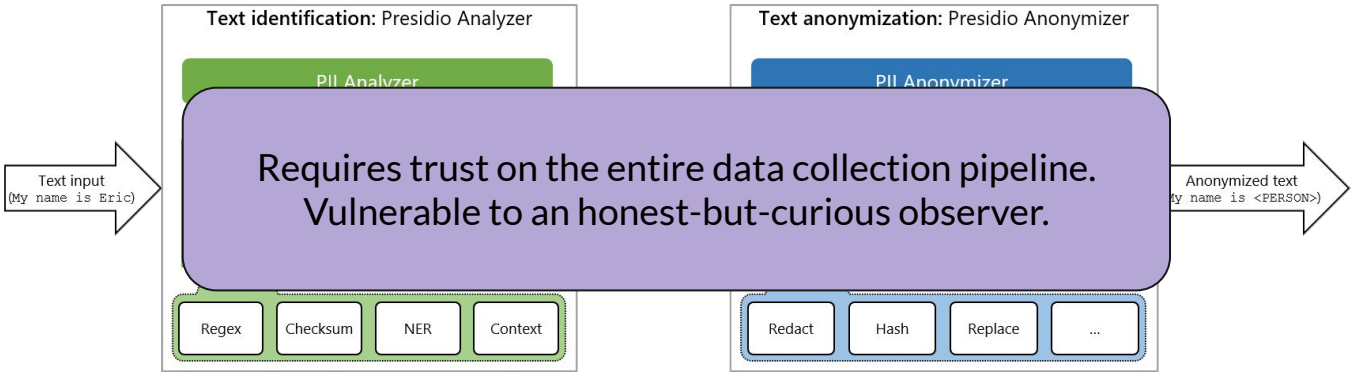
Lyons, Allan, et al. "Log: It's Big, It's Heavy, It's Filled with Personal Data! Measuring the Logging of Sensitive Information in the Android Ecosystem." ***(USENIX Security 23)***

Tradeoff between privacy and utility.

- PII data is present in the logs. *What can we do about it?*
- **Approach 1** : Redact all sensitive data.
- **Approach 2** : Sanitize logs through anonymization or removal.
- *Post hoc* or *a priori*?

Existing approaches : Microsoft Presidio.

- Current SOTA approach most widely used in production.
- Post-hoc model run by data aggregators after exfiltrating data from devices.



Existing approaches : OpenAI Privacy Filter.

- On-device SLM that detects and redacts PII data from logs.
- *a priori* mechanism, protects PII at the source.

Key Insight : Correlation not disclosure.

- Event timeline reconstruction is essential for forensic analysis.
- Redaction prevents data disclosure but breaks log fidelity for correlation.

Simple hashing or Pseudonymization also does not work.

“Harry Potter” → [Person]	Redaction, loses fidelity for correlation
“Harry Potter” → [a3bf450]	Allows correlation, but can break anonymity.

Key Insight : Correlation not disclosure.

- Event timeline reconstruction is essential for forensic analysis.
- Redaction prevents data disclosure but breaks log fidelity for correlation.

“We can

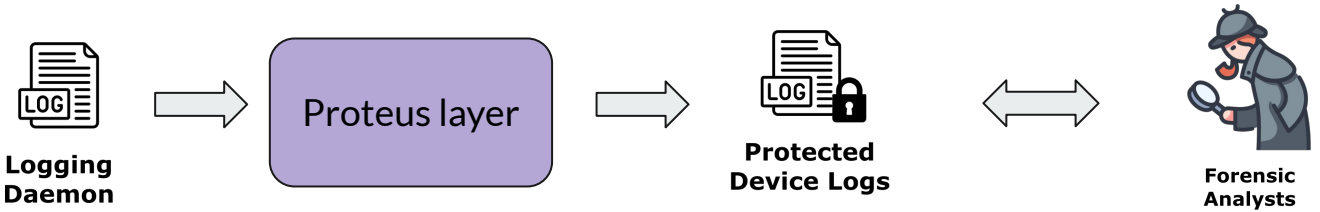
How do we balance disclosure while enabling correlation?

“Harry Potter” → [Person] Redaction, loses fidelity for correlation

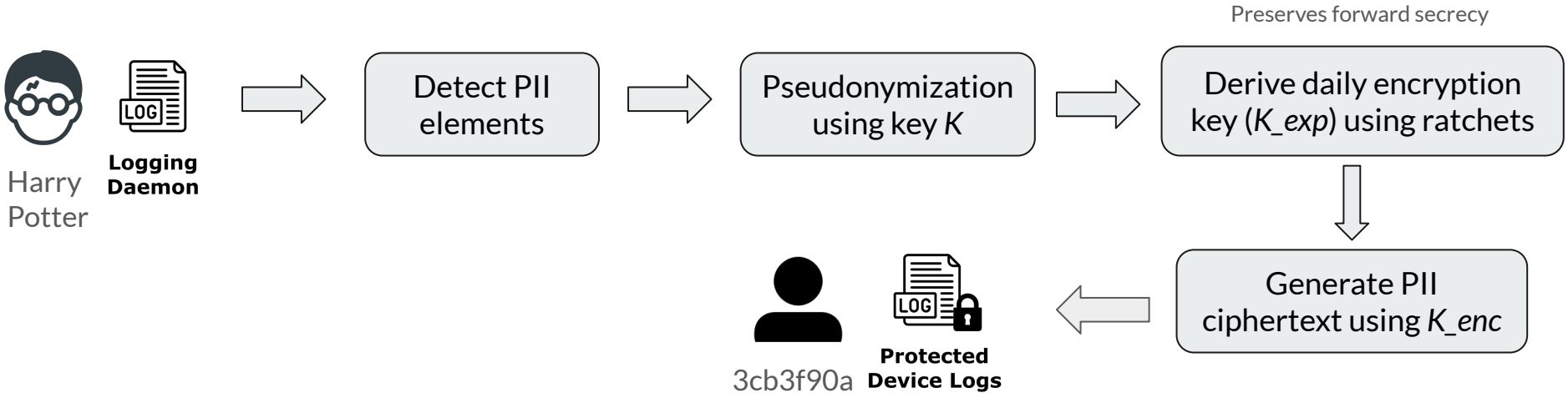
“Harry Potter” → [a3bf450] Allows correlation, but can break anonymity.

Proteus : Privacy-preserving logging framework.

- Transforms sensitive data before it enters the device log.
- Preserves search, debugging, and forensic fidelity of logs.
- Prevents plaintext exposure of PII across log exports.



Proteus : Log processing pipeline.



Logs only contain the ciphertext. Pseudonym is secured locally.

Proteus : Log reconstruction pipeline.

Protected Device Logs

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Request for controlled disclosure

Provide ratchet state of day *t-n*

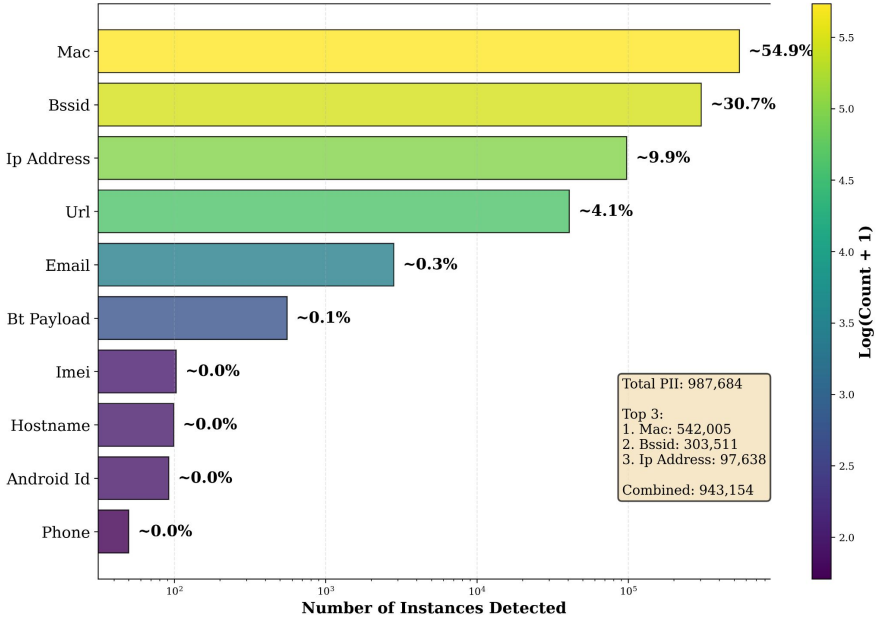
Derive daily decryption key (*K_exp*) for n days from t

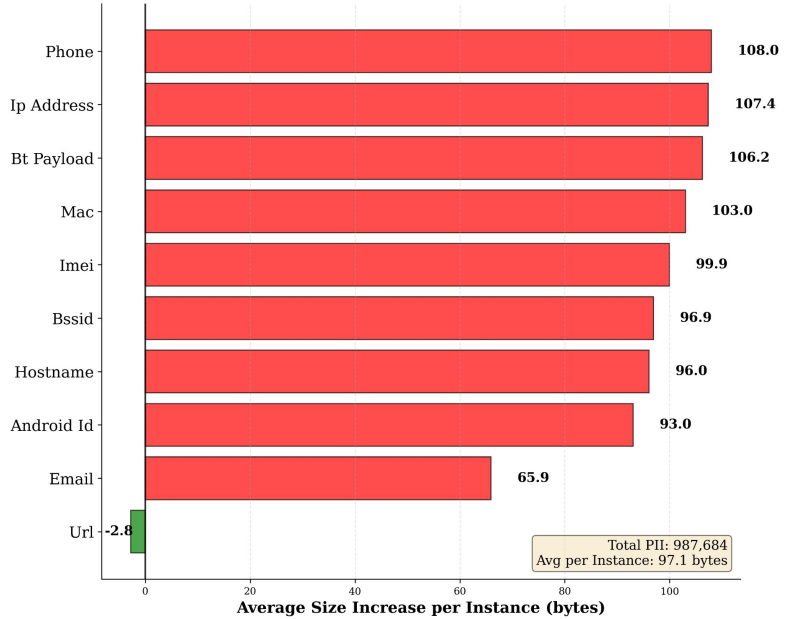
Generate PII pseudonymized text from ciphertext

man-12

Controlled disclosure reveals the pseudonyms used but not the actual PII.

Evaluation : Bulk processing.





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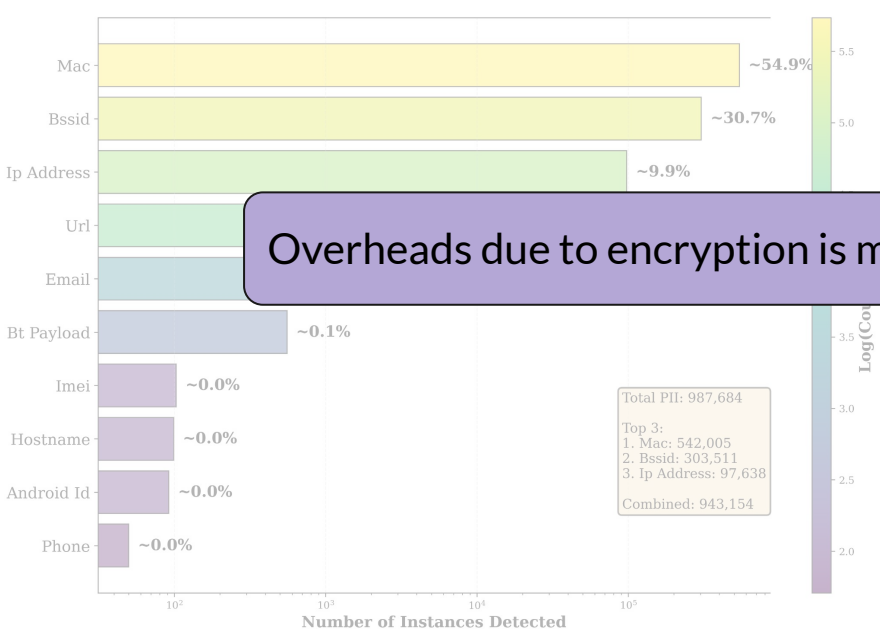
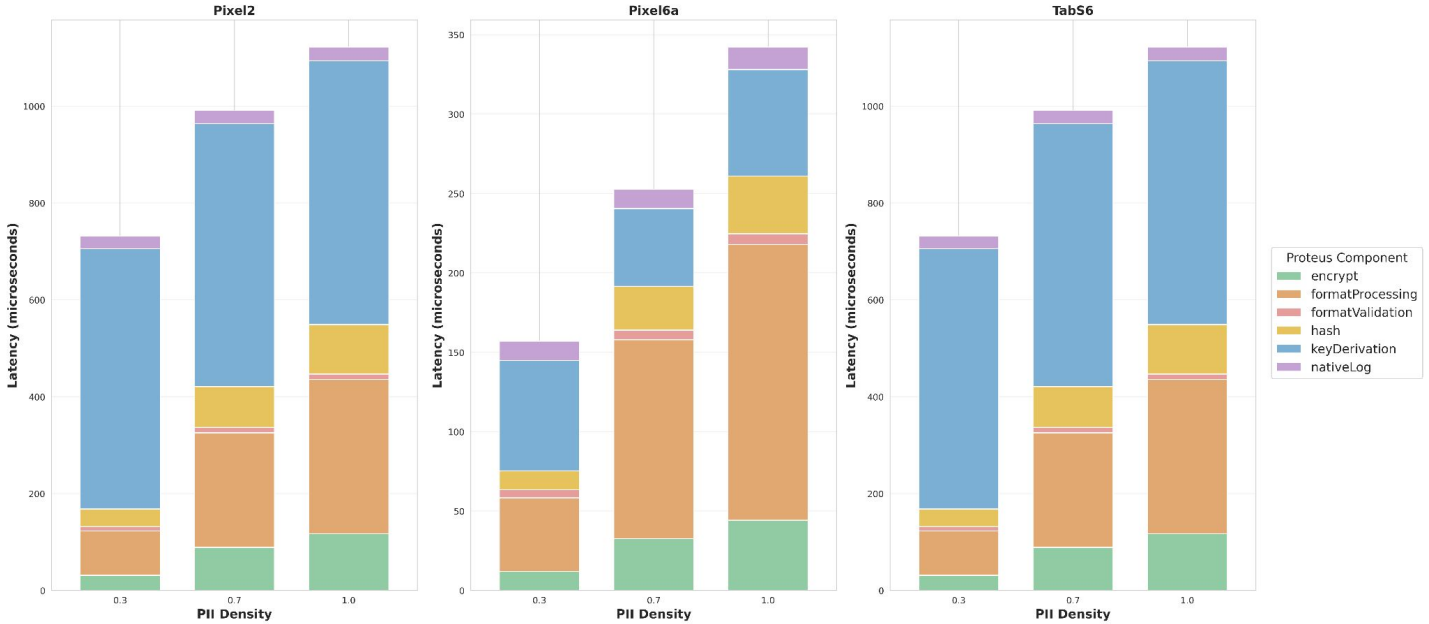


Overheads due to encryption is minimal, and in some cases *optimal*.

Evaluation : On-device measurement.



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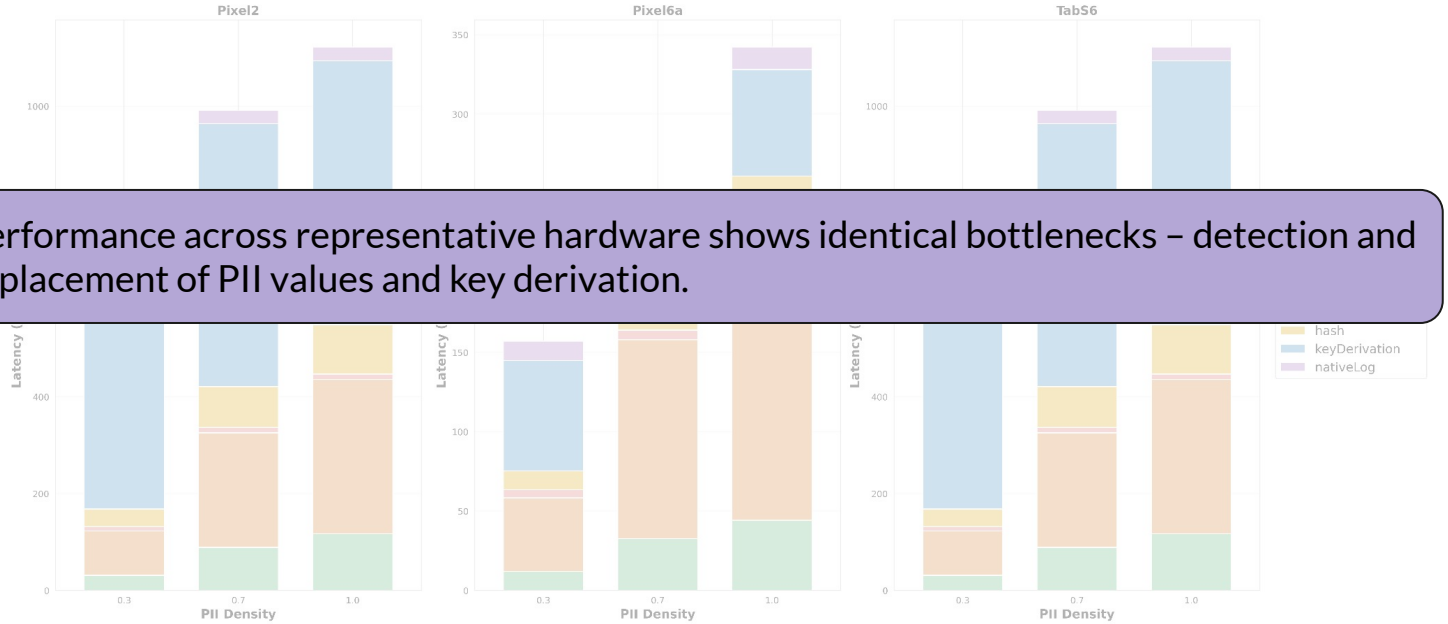

Performance across representative hardware shows identical bottlenecks – detection and replacement of PII values and key derivation.

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Takeaways

- Mobile devices are audit-critical systems. Increased logging exposes user privacy risks.
- **Proteus** presents a practical framework for protecting sensitive data in logs, while preserving full log fidelity.

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