BreakMi: Reversing, Exploiting and Fixing Xiaomi Fitness Tracking Ecosystem

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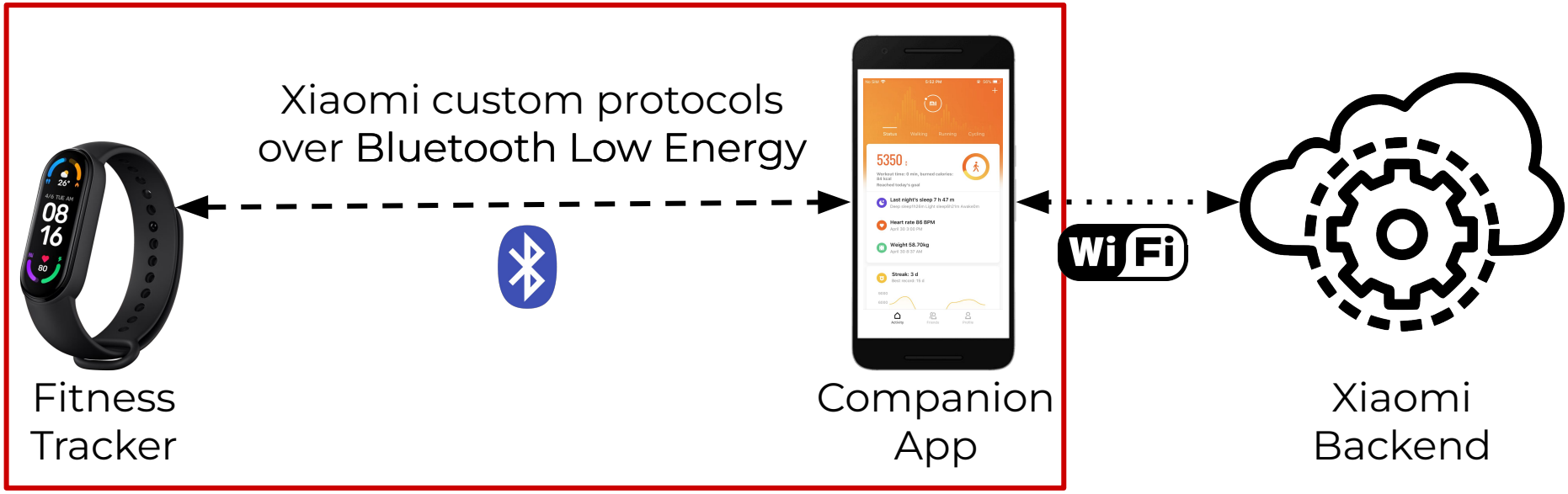
Motivations

- Fitness tracking ecosystems are pervasive
- **Critical** security and privacy concerns
  - Health data
- No **prior research** on Xiaomi despite being the market leader (19.6% share in 2021)
- Xiaomi ecosystem runs **proprietary** protocols
  - Attacks affect **millions** of devices regardless of hardware

Contributions

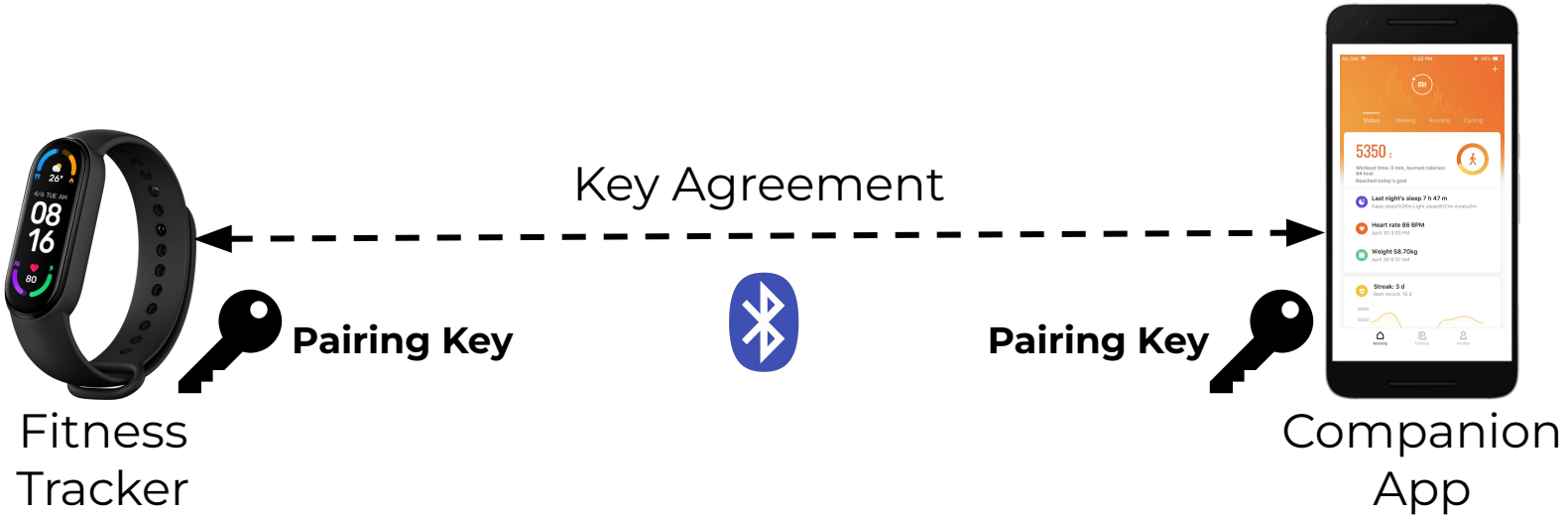
- Reversing Xiaomi **custom** protocols uncovering **severe** and **novel** vulnerabilities
- Deploying 6 **impactful** and **low-cost** attacks on the most recent trackers
- Open-sourcing **BreakMi**, an automated toolkit
- Fixing the protocols, and disclosing to Xiaomi
- Comparison with Fitbit ecosystem

System Model

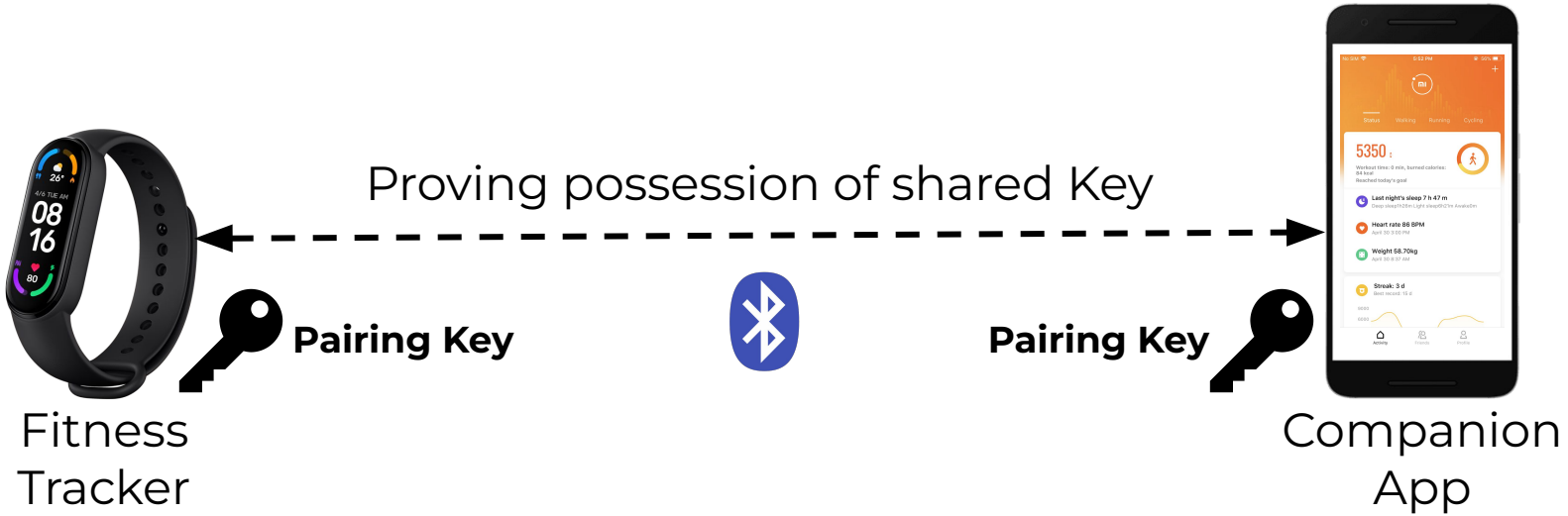


Our main focus

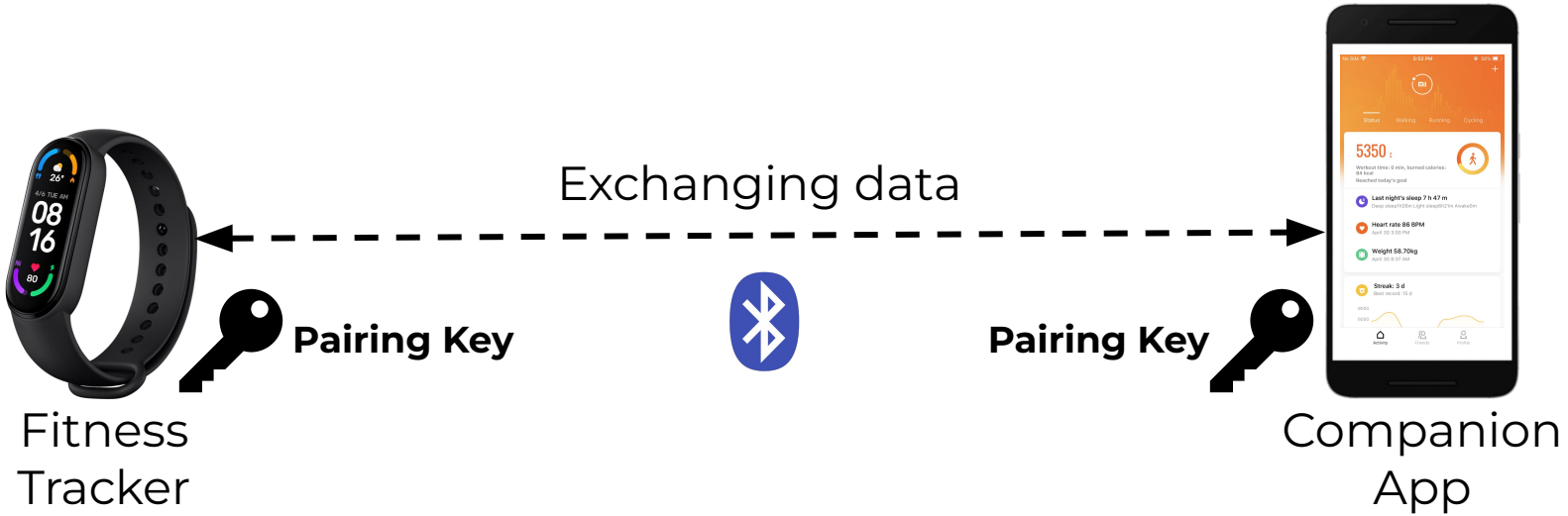
Pairing


Key Agreement
Pairing Key
Pairing Key
Fitness Tracker
Companion App

Authentication



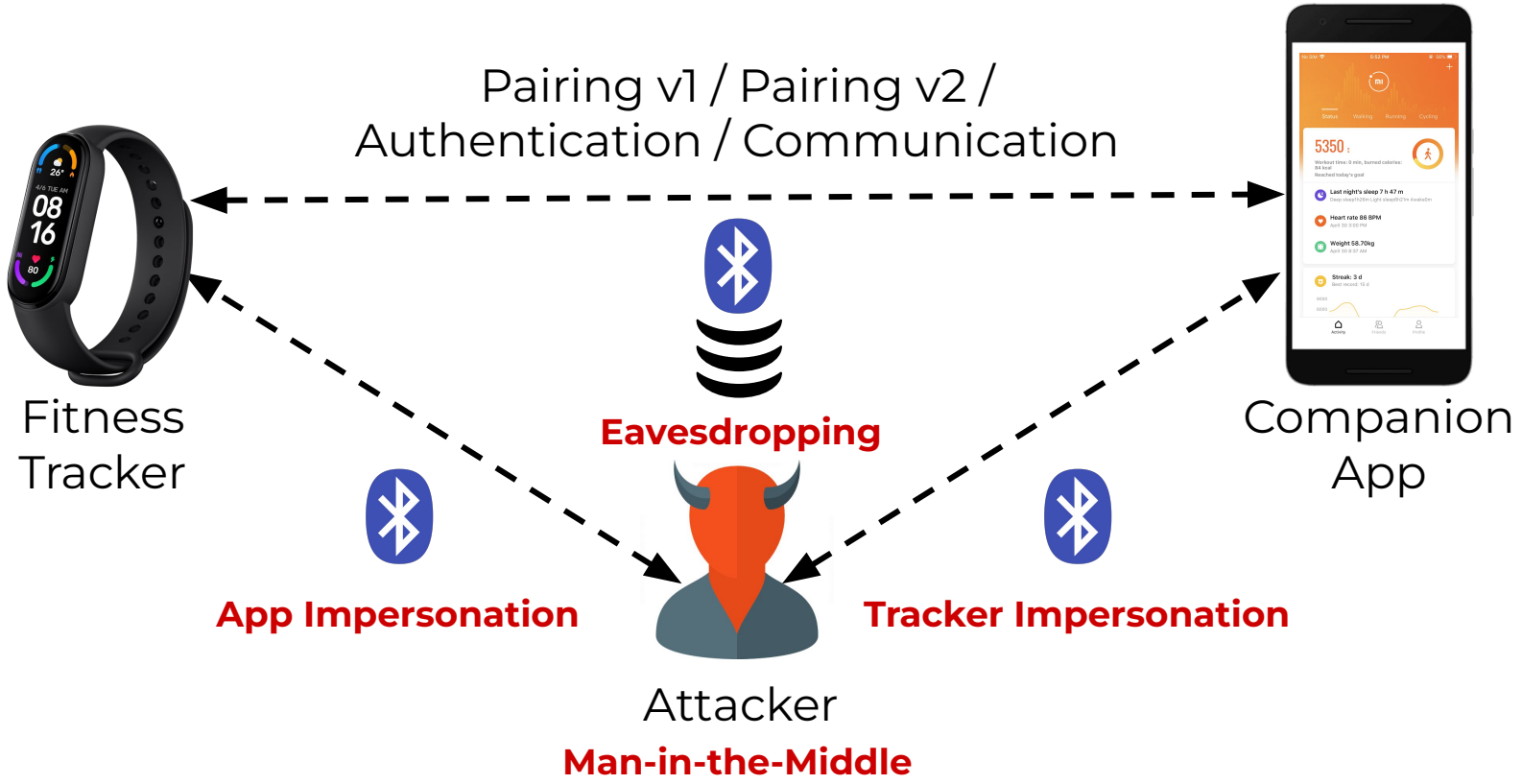
Communication



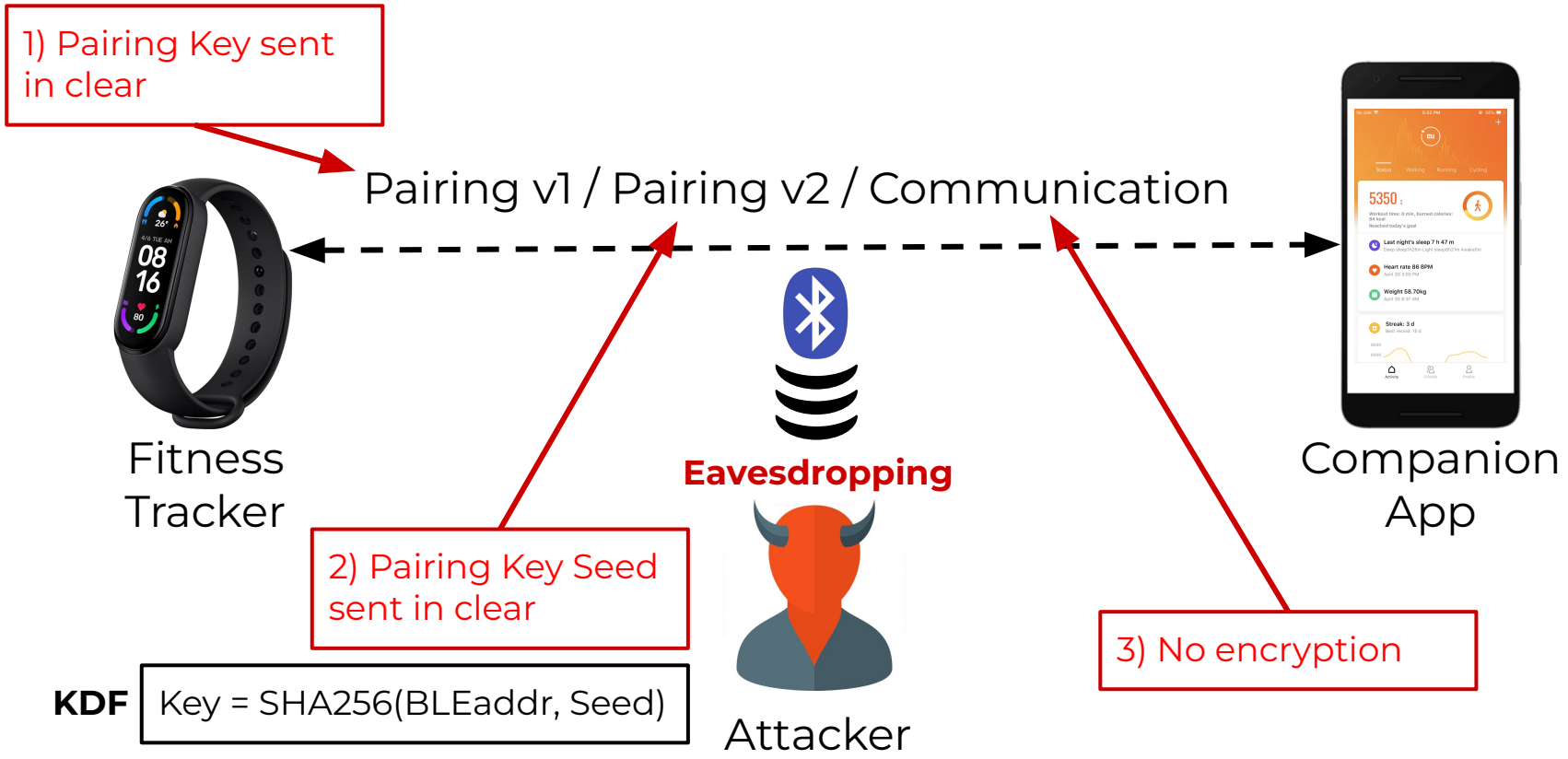
Proximity Attacks

- Four proximity over-the-air attacks
  - Eavesdropping
  - Tracker Impersonation
  - App Impersonation
  - Man-in-the-Middle

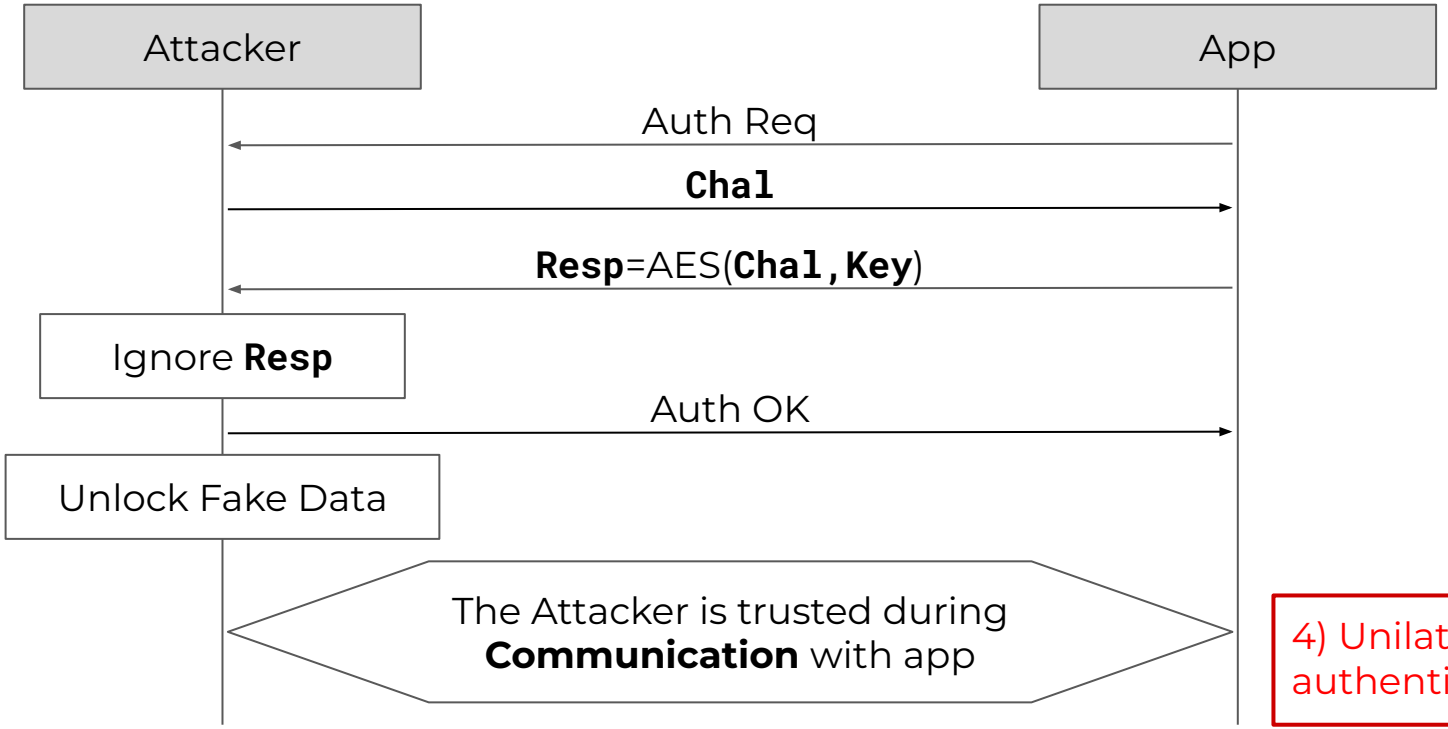
Proximity Threat Model



Proximity Eavesdropping

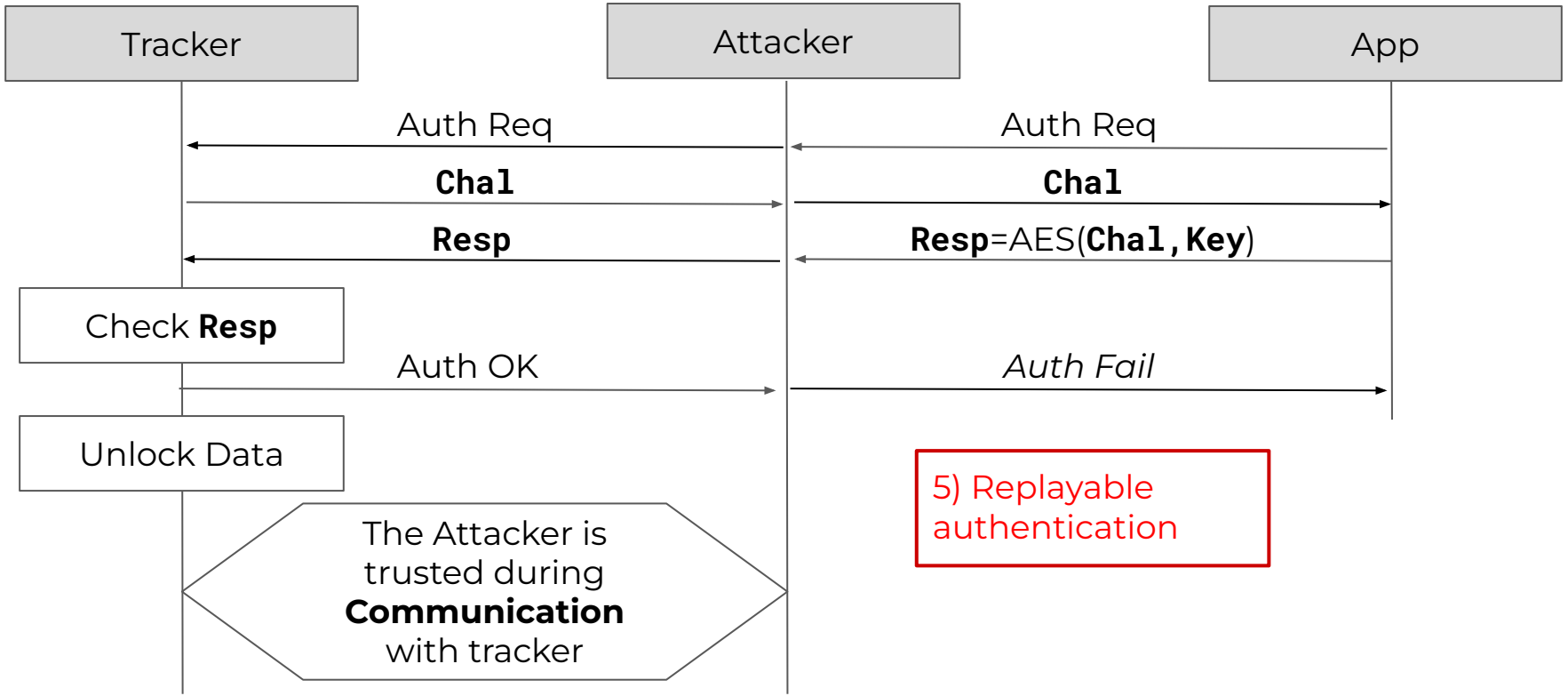


Proximity Tracker Impersonation

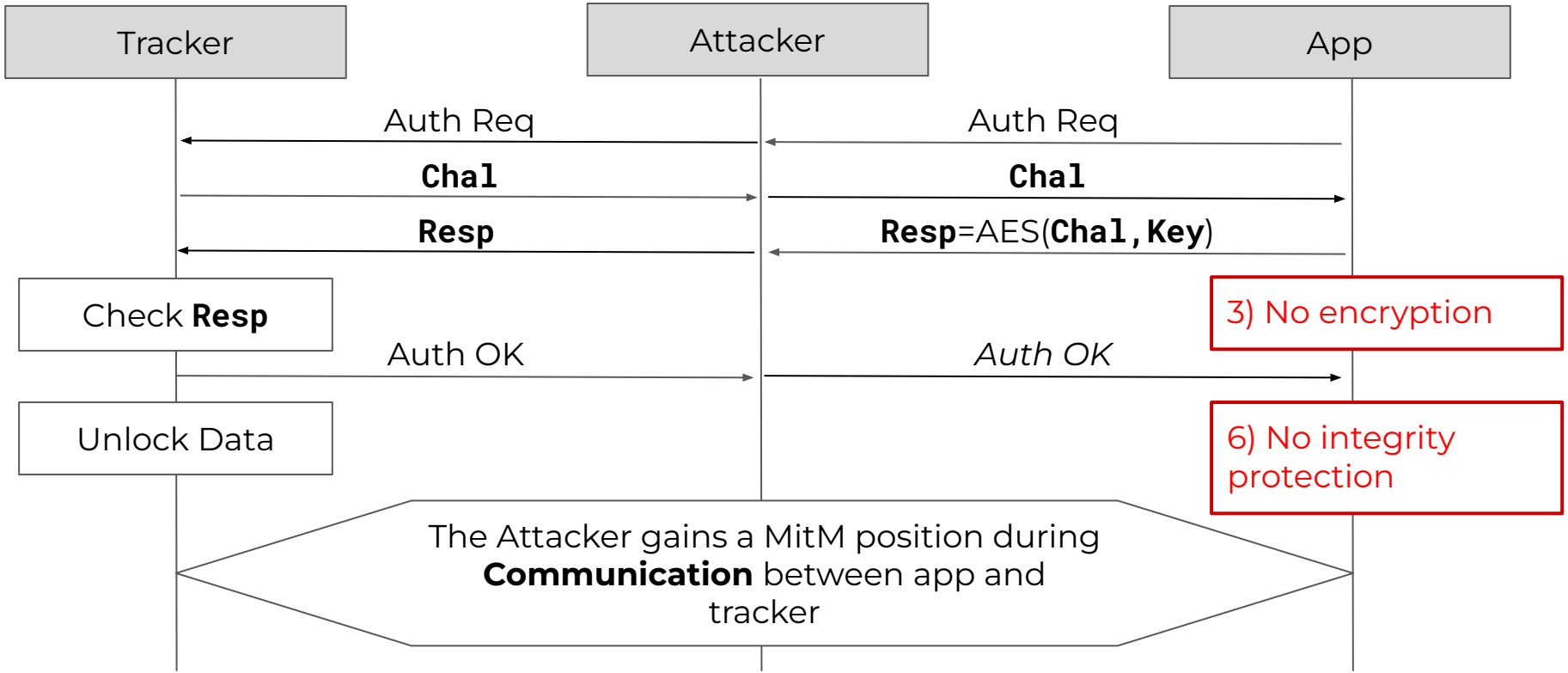


4) Unilateral app authentication

Proximity App Impersonation



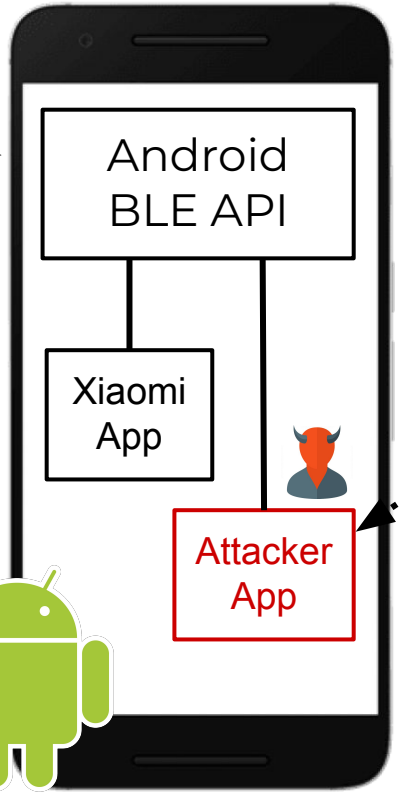
Proximity Man-in-the-Middle



Remote Attacks

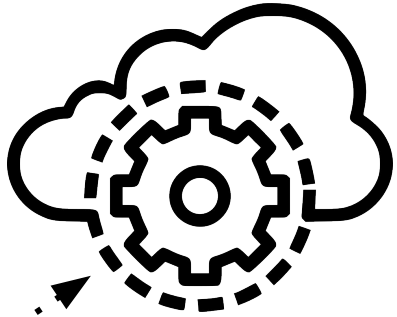
- Two remote software-based attacks
  - Eavesdropping
  - App Impersonation

Remote Threat Model

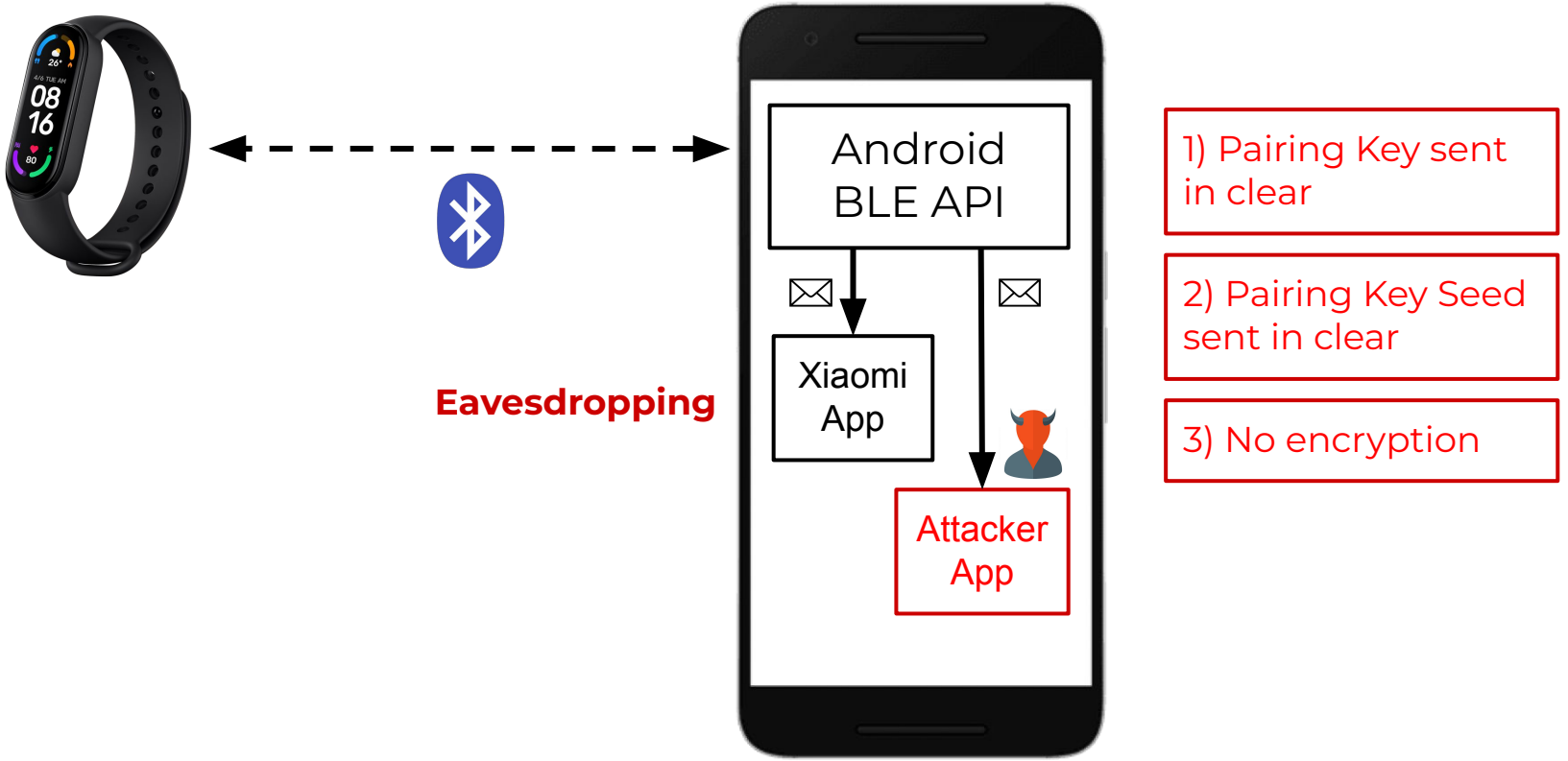


Eavesdropping

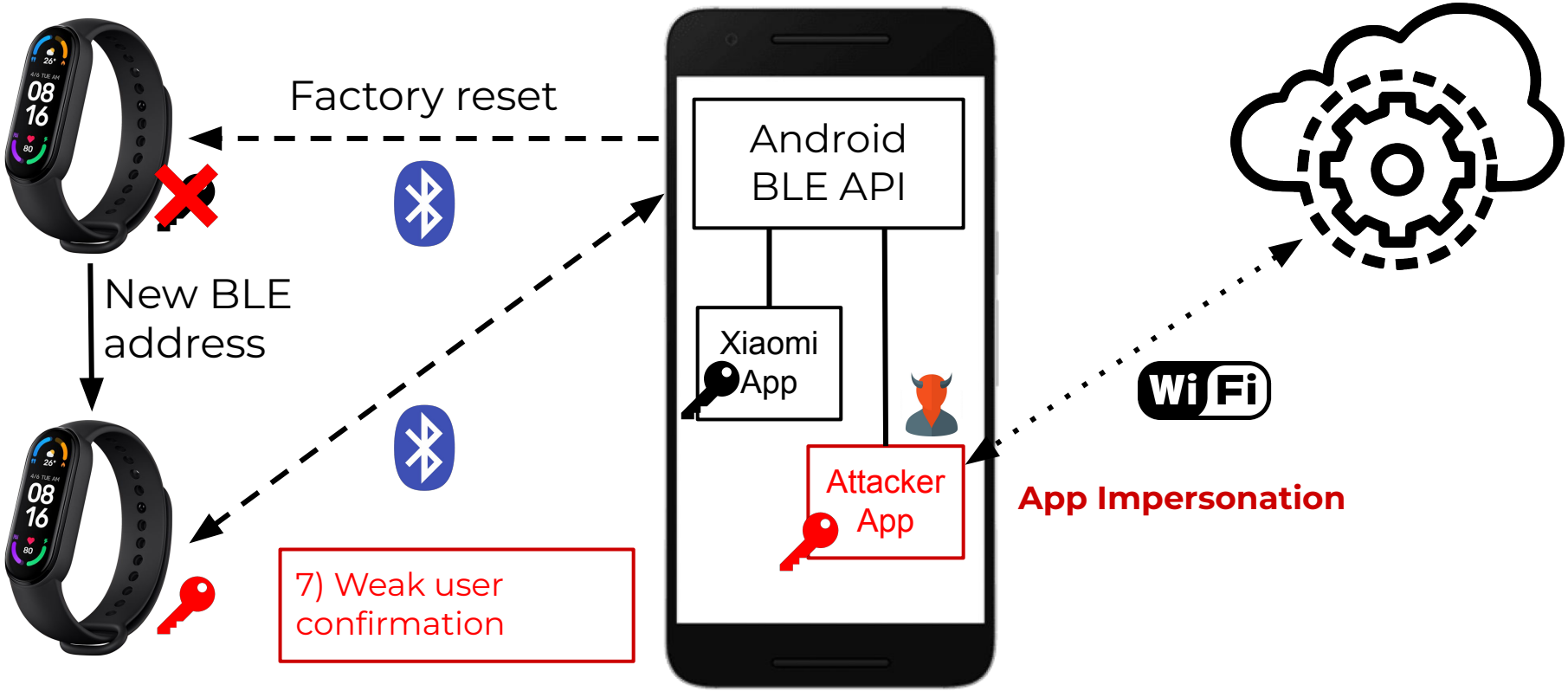
App Impersonation



Remote Eavesdropping



Remote App Impersonation



Evaluation Setup

Tracker	Release Year	Pairing Version	Bluetooth Version	LE Secure Conn.	Link Layer Security
Mi Band 2	2016	1	4.2	✗	✔
Mi Band 3	2018	1	4.2	✗	✔
Cor 2	2019	1	4.2	✗	✔
Mi Band 4	2019	2	5.0	✔	✔
Mi Band 5	2020	2	5.0	✔	✔
Mi Band 6	2021	2	5.0	✔	✔

Evaluation Setup - cont.

App	App Version	Year	OS
Zepp Life (formerly Mi Fit)	4.8.1	2020	Android
Zepp (formerly Amazfit)	5.9.2	2021	Android

- Acer Aspire 3 laptop
- CSR8510 A-10 Controller
- BLE sniffer (BBC Micro Bit + btlejack)

Evaluation Results

	Proximity Attacks				Remote Attacks	
	Trac Imp.	App Imp.	MitM	Eavesdr.	App Imp.	Eavesdr.
Zepp Life	n/a	✔	✔	✔	✔	n/a
Zepp	n/a	✔	✔	✔	✔	n/a
Mi Band 2	✔	n/a	✔	✔	n/a	✔
Mi Band 3	✔	n/a	✔	✔	n/a	✔
Amazfit Cor 2	✔	n/a	✔	✔	n/a	✔
Mi Band 4	✔	n/a	✔	✔	n/a	✔
Mi Band 5	✔	n/a	✔	✔	n/a	✔
Mi Band 6	✔	n/a	✔	✔	n/a	✔

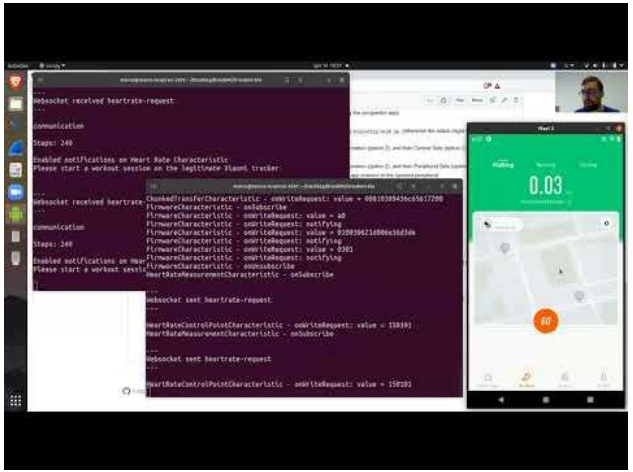
Vulnerable Android Versions (stats)

Smartphone	Android Version	Remote Attacks	
		Eavesdropping	App Impersonation
Pixel 4A	12 (23.58%)	✔*	✔*
Pixel 2XL	11 (27.96%)	✔	✔
Pixel 2XL	10 (20.98%)	✔	✔
Galaxy J5	9 (10.58%)	✔	✔
Redmi 5 Plus	8 (8.08%)	✔	✔
Galaxy S5	6 (2.25%)	✔	✔

** Requires dangerous runtime permission `BLUETOOTH_CONNECT`*

BreakMi

- BreakMi on Github
- Attack videos on Youtube
  - Xiaomi and Fitbit
- CHES Artifact approval



Proximity Man-in-the-Middle demo

Conclusion

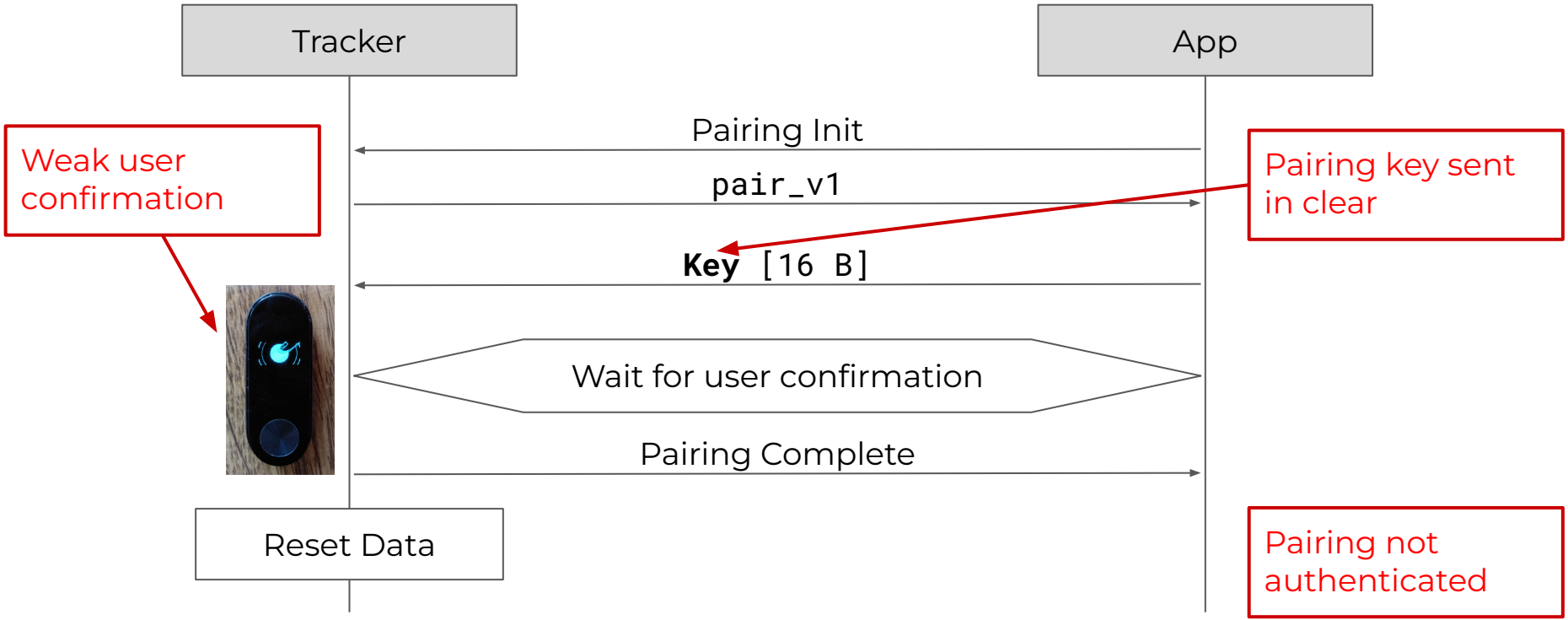
- Reversing Xiaomi **custom** protocols uncovering **severe** and **novel** vulnerabilities
- Deploying 6 **impactful** and **low-cost** attacks on the most recent trackers
- Open-sourcing **BreakMi**, an automated toolkit
- Fixing the protocols, and disclosing to Xiaomi
- Comparison with Fitbit ecosystem

BACKUP SLIDES

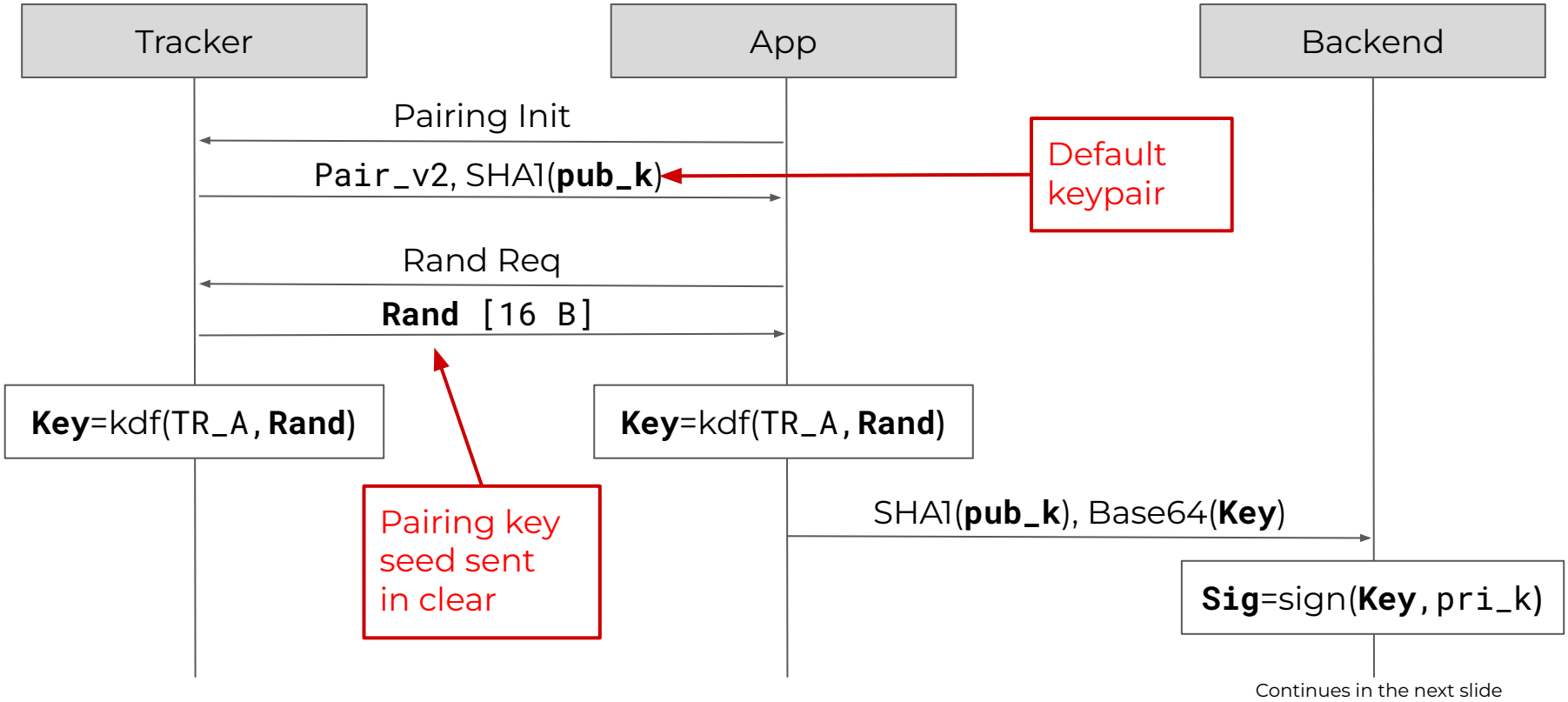
Summary

- Cover slide
- Threat model (system + protocols + attacker model)
- Summary of 4 OTA attacks (TI, AI, MitM, Eave)
- Describe OTA attacks , related vulns, remember RE
- Remote attacks (AI, Eave)
- Evaluation (trackers, apps, results)
- Countermeasures (optional)
- Conclusions

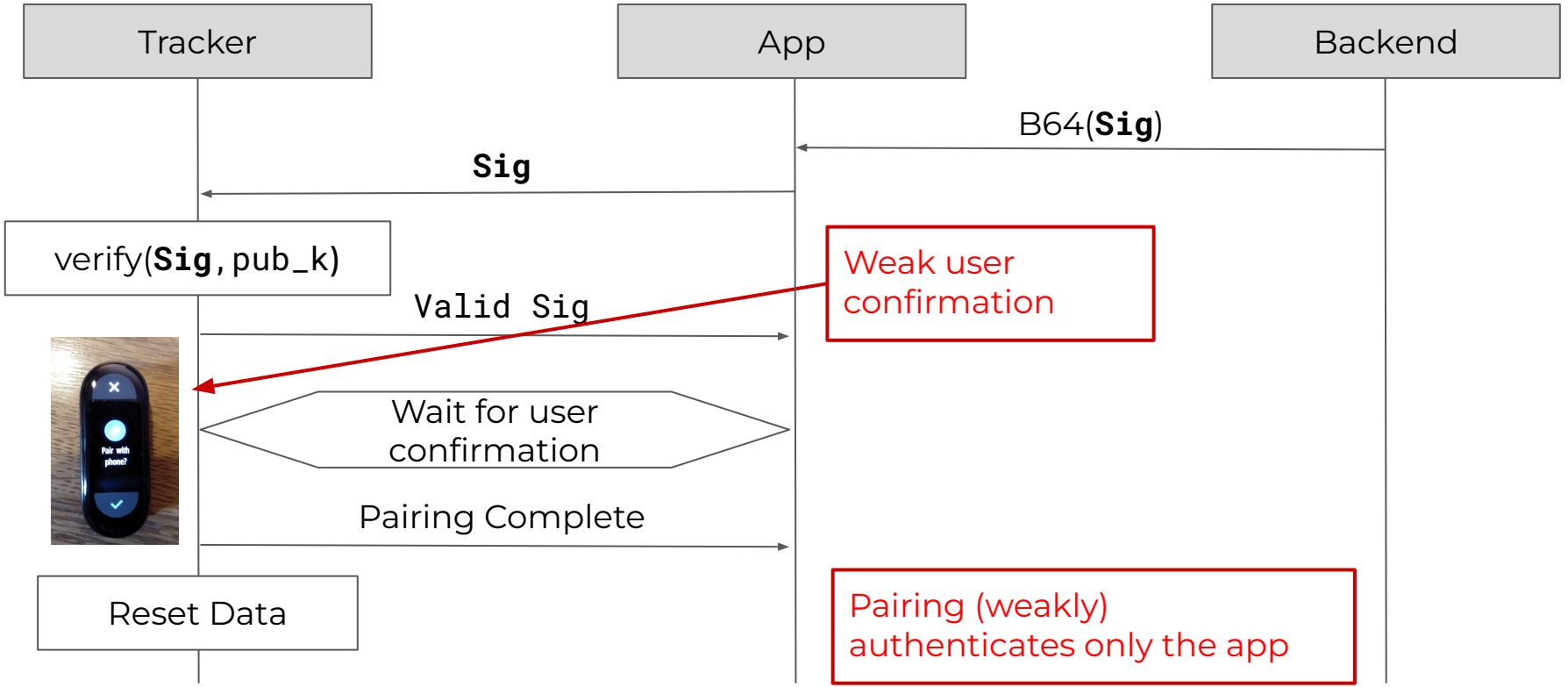
Pairing v1


Tracker
App
Pairing Init
pair_v1
Key [16 B]
Wait for user confirmation
Pairing Complete
Reset Data
Weak user confirmation
Pairing key sent in clear
Pairing not authenticated

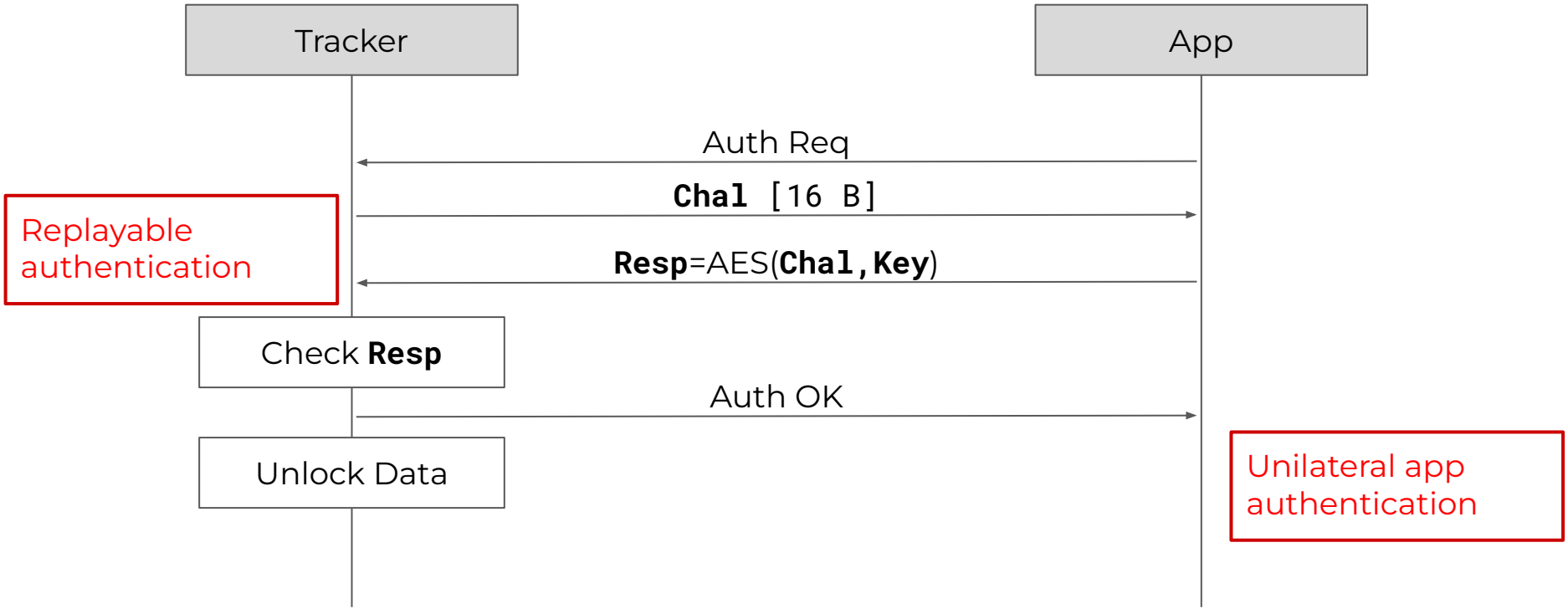
Pairing v2


Tracker
App
Backend
Pairing Init
Pair_v2, SHA1(pub_k)
Default keypair
Rand Req
Rand [16 B]
Key=kdf(TR_A, Rand)
Key=kdf(TR_A, Rand)
Pairing key seed sent in clear
SHA1(pub_k), Base64(Key)
Sig=sign(Key, pri_k)
Continues in the next slide

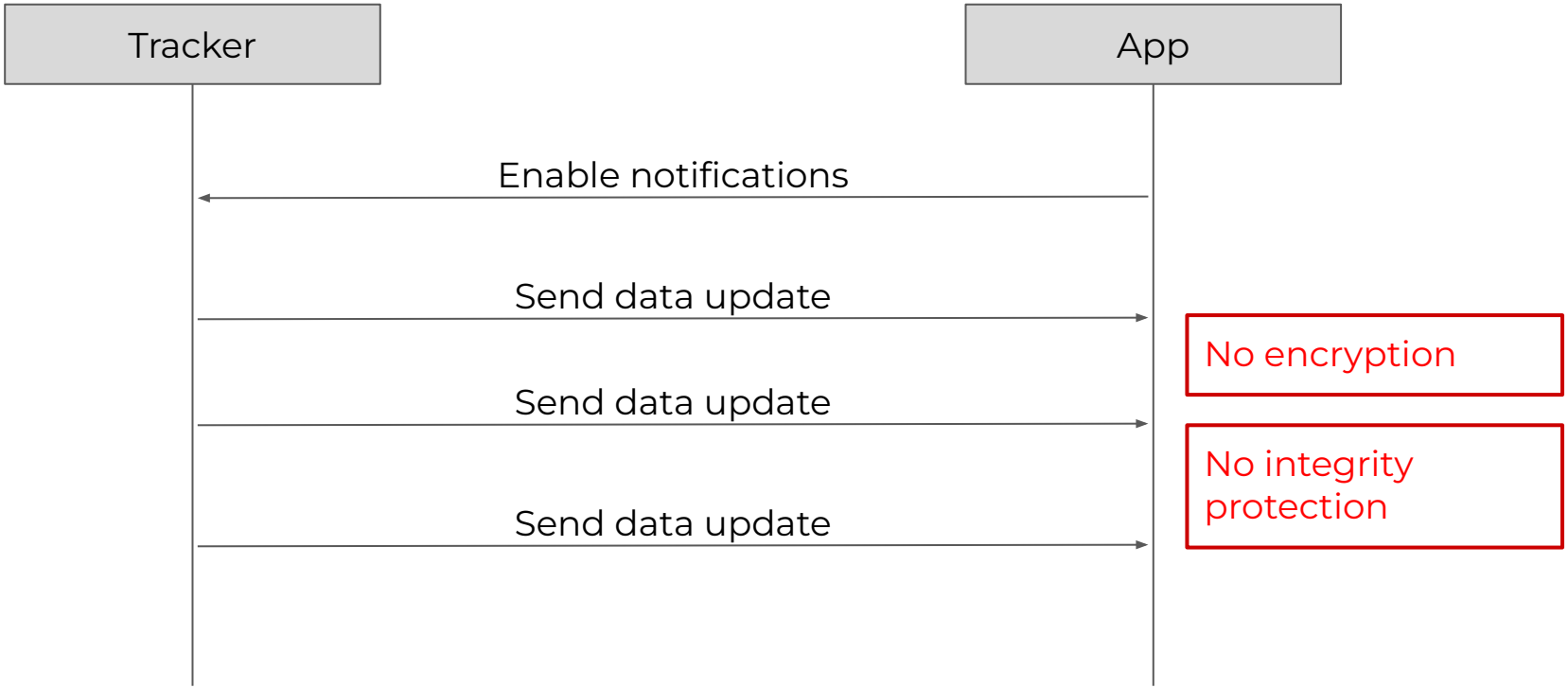
Pairing v2 - cont.



Authentication



Communication



Speaker Info

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S3 System Security Research Group

Research Topics:

- Bluetooth / Bluetooth Low Energy
- IoT
- Android

Market Share

Vendor	Q2 2021 Shipments	Q2 2021 Market Share	Q2 2020 Shipments	Q2 2020 Market Share
Xiaomi	**8.0m**	**19.6%**	**7.8m**	**20.1%**
Apple	7.9m	19.3%	6.1m	15.8%
Fitbit	3.0m	7.3%	2.5m	6.4%
Others	22m	53.8%	22.3m	57.7%
Total	40.9m	100%	38.7m	100%

Canalys wearable band analysis August 2021 [source]

Countermeasures

1. **(Authenticated) Key Establishment**
   - Tracker and app generate a keypair, sharing the public key
   - Both perform Diffie-Hellman to generate a `SharedSecret`

2. **Strong Pairing Confirmation**
   - Both exchange nonces and calculate confirmation value
   - User confirmation if values match

Countermeasures

3. **Strong Key Authentication**
   - Need for mutual authentication
   - Tracker and app exchange `ChalApp` and `ChalTra`
   - `Resp1`, `Resp2` = HASH(`SharedSecret`, `ChalApp`, `ChalTra`)
   - Responses are checked

Countermeasures

4. **Authenticated Encryption**
   - Need for encrypted Communication session
   - Tracker and app exchange nonces
   - `SessionKey` = HKDF(`SharedSecret`,`NonceApp`,`NonceTra`)
   - AES-CCM encrypted session using `SessionKey`

5. **BLE Link-Layer Security**
   - Complementary to Application-Layer Security
   - Enable LE Secure Connections feature on Mi Band 4/5/6