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Privacy-preserving Wi-Fi tracking systems

Célestin Matte, Marine Minier, Mathieu Cunche, Franck Rousseau

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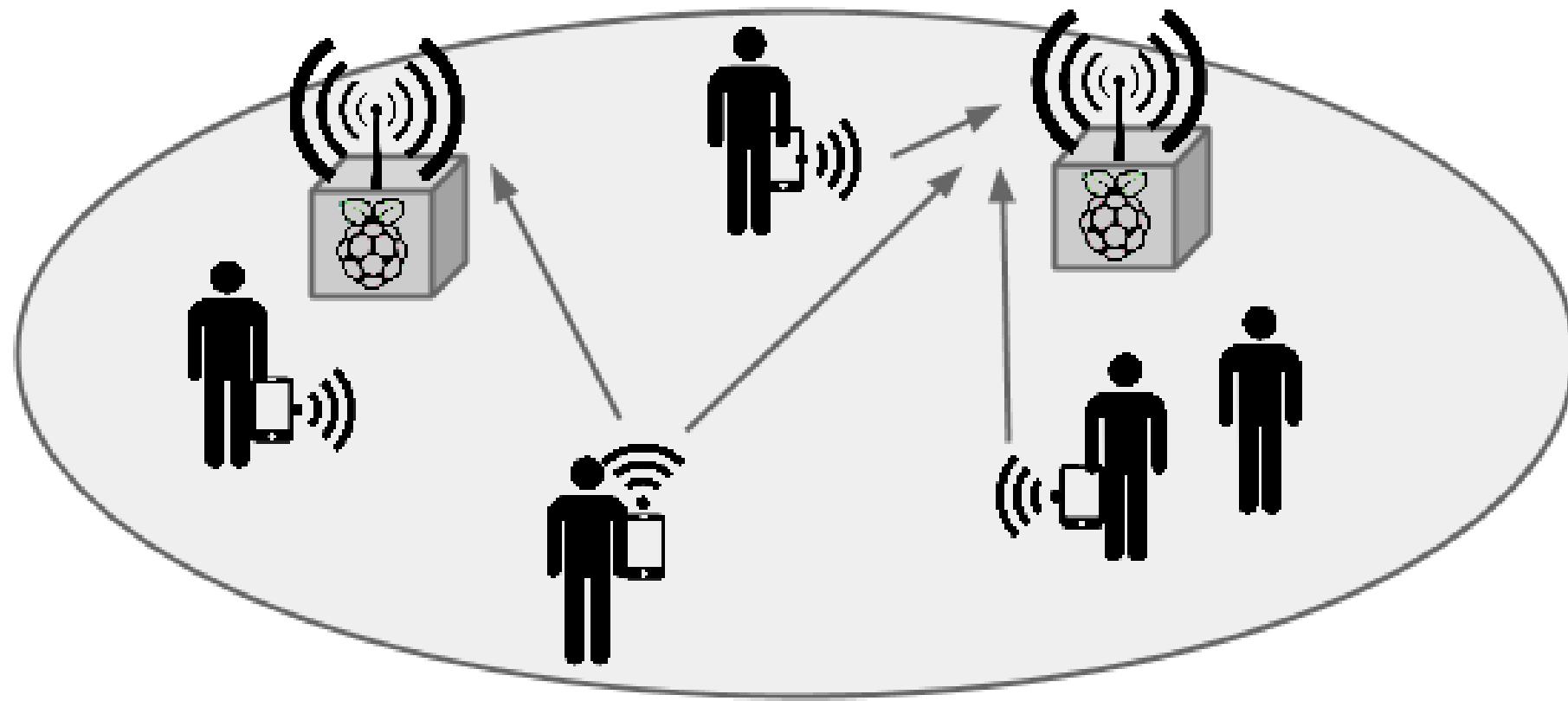
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WI-FI TRACKING SYSTEMS

- ▶ Wi-Fi-enabled smartphones frequently emit frames because they scan for access points
- ▶ Each frame contains a unique identifier of the device: the **MAC address**
- ▶ Wi-Fi tracking systems monitor and store these frames in order to make statistics:
 - ▶ number of visitors
 - ▶ frequency of visits
 - ▶ travel paths
 - ▶ etc.



PRIVACY ISSUES

- ▶ Lot of private information stored - much more than needed to make basic statistics
- ▶ Anyone with access - legitimate or not - to that data can get a lot of information about passers-by
- ▶ In France, made illegal by the "Informatique et Liberté" law (LIL). The CNIL made precise recommendations for this case of information collecting so that one knows if they respect the law [1]:
 - ▶ Data must be deleted when the person exits the place
 - ▶ Used algorithm must ensure a strong collision rate, i.e. an identifier must correspond to several people
 - ▶ People must give their explicit consent if one wants to store data for a longer period (opt-in system).
- ▶ We can work on storing only information valuable for statistics
- ▶ There is no miracle solution
- ▶ We aim to propose a privacy/utility tradeoff

OBJECTIVES

- ▶ Short term:
 - ▶ First, comparing the different methods
 - ▶ Finding a good privacy metric
- ▶ Long term:
 - ▶ Having a ready-to-use system with the same functionalities than existing Wi-Fi tracking systems, augmented with privacy-by-design

DATA COLLECTION

- ▶ We need datasets to perform all our tests, containing logs of raw MAC addresses seen at a certain time at a certain place.
- ▶ Legislation forbids the collection of such datasets, as they contain personal identifiers
- ▶ Need consent of all concerned people
 - ▶ difficult to set up
- ▶ Possible solutions:
 - ▶ getting the consent of concerned people (one try at ACM Middleware, small dataset obtained)
 - ▶ generate synthetic datasets from models

PRIVACY METRICS

- ▶ We need metrics to quantify "privacy", in order to evaluate our methods
- ▶ Possible metrics are (non-exhaustive list):
 - ▶ K-anonymity
 - ▶ Collision rate: how many devices may be identified by the same identifier?
 - ▶ entropy?
- ▶ Other considerations:
 - ▶ Is the collision rate evenly distributed?
 - ▶ What happens on extreme values? (e.g. very few number of passers-by)
- ▶ We have to determine which one (among these ones or other ones) best fits our needs

HASHING

- ▶ **Principle:** Using a simple cryptographic hash function, such as MD5 or functions of the SHA family, with no salt
- ▶ **Problems:**
 - ▶ Easy to reverse in the case of MAC addresses [2]
 - ▶ Almost no collision
 - ▶ Almost useless

aa:bb:cc:dd:ee:ff $\xrightarrow{\text{sha1sum()}}$ fc06e09ced76b0f3510cd617c36929aae08023be

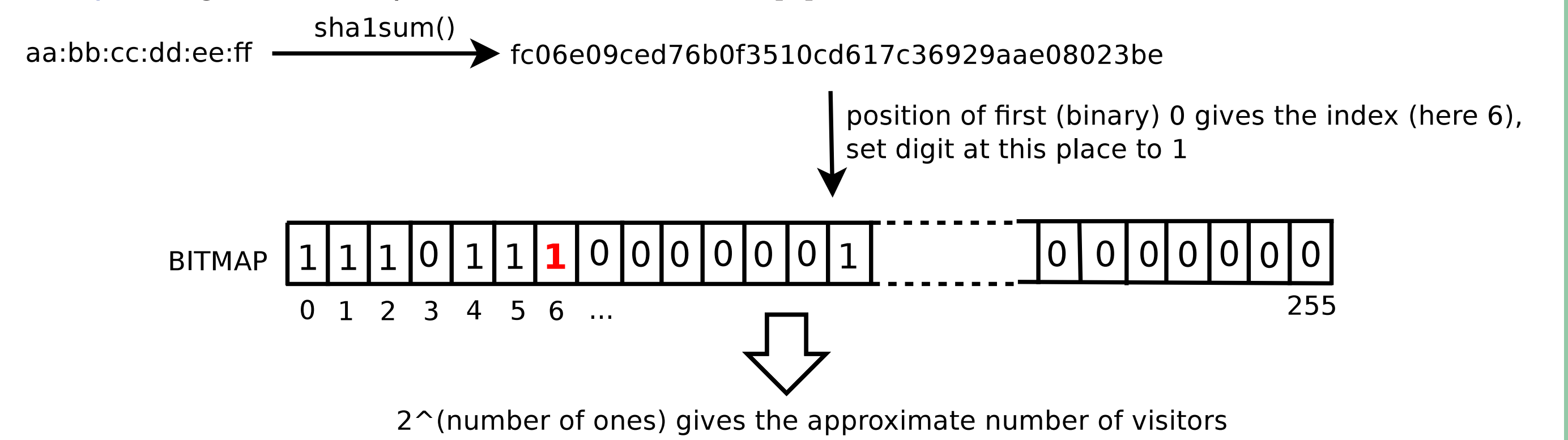
HASHING AND TRONCATION

- ▶ **Principle:** Same as hashing, but only keep a small part of the result
- ▶ the less you keep, the more collisions you'll get
- ▶ Also possible to truncate before hashing, in order to manually increase collision rate (first 3 bytes of the MAC address are the constructor identifier)
- ▶ **Problem:** Still easy to reverse?

aa:bb:cc:dd:ee:ff $\xrightarrow{\text{sha1sum()}}$ fc06e09ced76b0f3510cd617c36929aae08023be $\xrightarrow{\text{truncate()}}$ fc06e09

BITMAPS

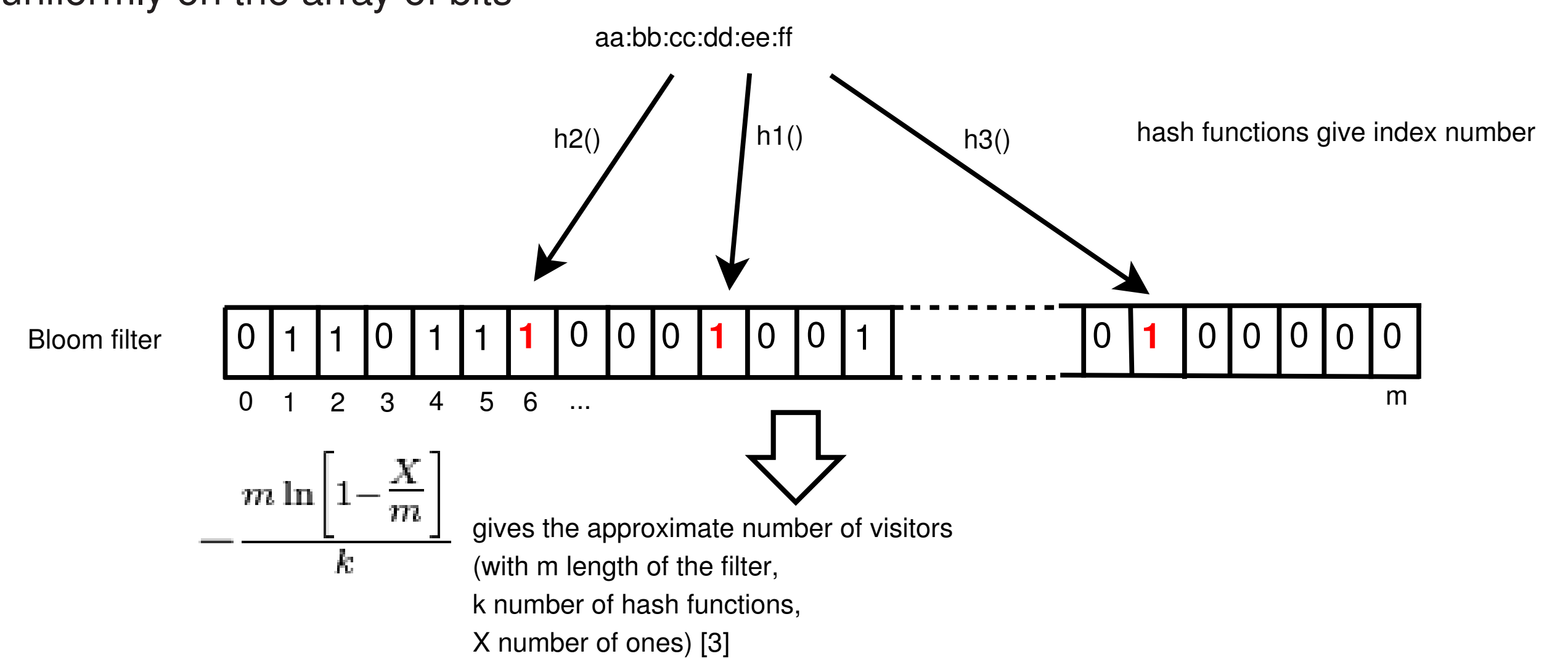
- ▶ **Principle:** logarithmic repartition of the hashes [4]



- ▶ **Problems:**
 - ▶ Unequal collision probability (half MAC addresses will set first bit or one while only one will set the last bit to one)
 - ▶ Very approximate for low numbers of MAC addresses (which is our case most of the time)

BLOOM FILTERS

- ▶ Data structure useful for many applications
- ▶ Insertion and search in $O(1)$
- ▶ ...but false positives
- ▶ ...which we use for privacy purpose
- ▶ We aim to be able to say that a person *may* have been here, but never be sure about it
- ▶ **Principle:** about the same as bitmaps, but use several hashing functions spreading bits uniformly on the array of bits



- ▶ **Problems:**
 - ▶ It may be possible to know for sure that some MAC addresses were seen
 - ▶ May still give bad results for low numbers of MAC addresses (tests ongoing)

OTHER POSSIBILITIES

- ▶ Using other phone characteristics instead of MAC addresses (plenty of fingerprinting techniques exist) [5]
- ▶ Hashing with salts (keys), and destroying keys after a predefined period of time. Key destruction is not a trivial problem.

DEPLOYMENT

- ▶ Simple tools: raspberry pis with Wi-Fi dongles



- ▶ Partnership with UrbaLyon
- ▶ Searching for partners with an infrastructure to share (electricity + network access)

FUNDING

- ▶ Project funded by Academic Research Community (ARC), Rhône-Alpes region (ARC 7).



REFERENCES

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- [2] Demir, Levent and Cunche, Mathieu and Lauradoux, Cédric Analysing the privacy policies of Wi-Fi trackers and statistics.
- [3] Swamidass, S. Joshua; Baldi, Pierre (2007) Mathematical correction for fingerprint similarity measures to improve chemical retrieval
- [4] Flajolet, Philippe and Martin, G Nigel Probabilistic counting
- [5] Xu, Qiang and Zheng, Rong and Saad, Walid and Han, Zhu Device Fingerprinting in Wireless Networks: Challenges and Opportunities