Mobile Health
Lecture 10
Radios, Bluetooth and Contact Tracing

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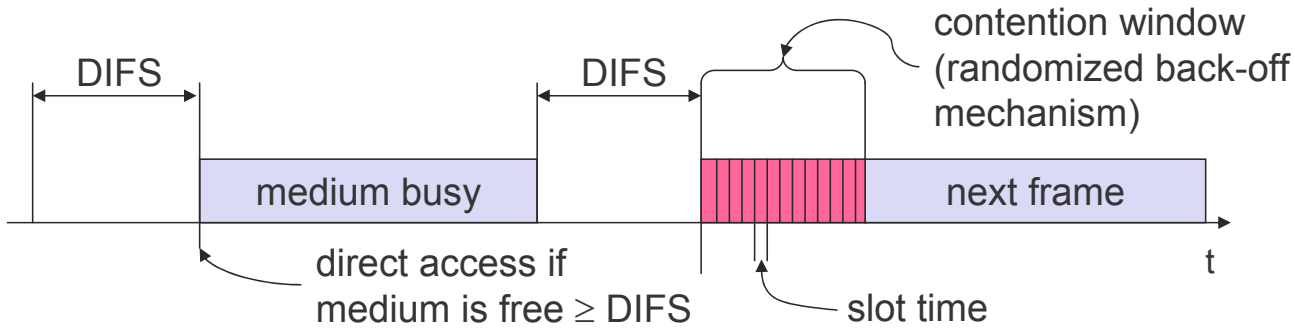
Radios

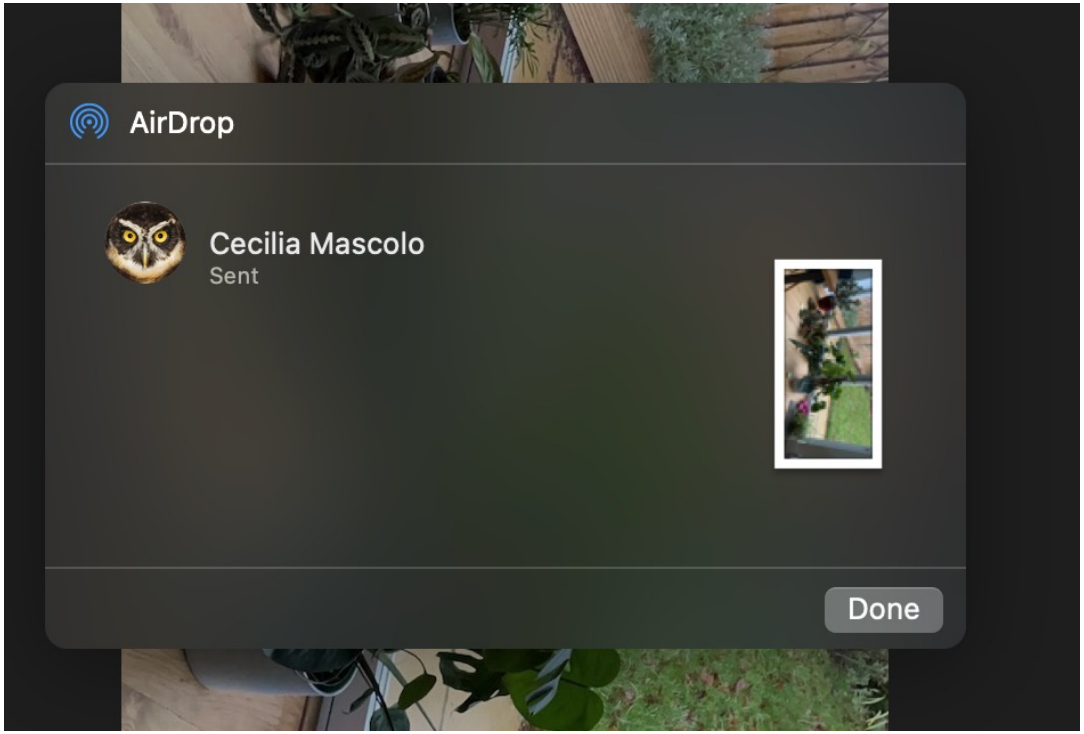
- Wearable/mobile device sensors have multiple radios which are used to detect presence in a location as well as contact.
  - Global Positioning System
  - Bluetooth
  - WiFi
  - Cellular
  - RFID
  - …
- Technologies differ broadly in range, architecture and energy efficiency

WiFi Radio (802.11)

- Standards for communication for local area networks
- Client/server and peer to peer modes
- 11 Mbps to 20 Gbps
- Communication over frequency channels (some multiplexing at various levels, spatial, coding, time too).
- MAC layers support carrier sense multiple access with collision avoidance (CSMA/CA)



Low range ad hoc connectivity

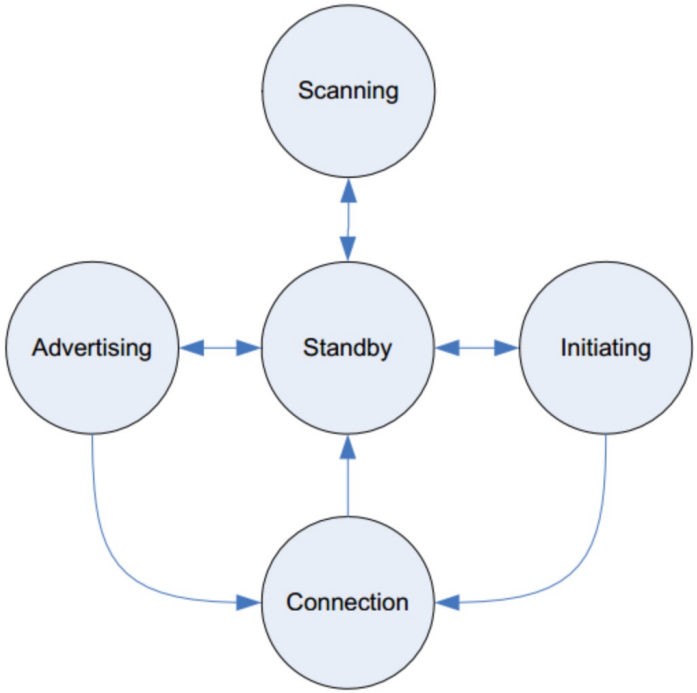


Bluetooth Low Energy (BLE)

- Low connectivity range
- Low energy consumption
- 2.4 GHz band
- Transmission rate 1Mbps (going on 2Mbps)
- 40 channels separated by 2MHz (3 advertising channels)
- Central (e.g. Phones) and Peripheral Devices

BLE States

- A device has 5 states:
  - Scanning (listening)
  - Advertising (at interval)
  - Standby
  - Initiating
  - Connection
- Peripheral devices only advertise
- Central devices also scan



BLE Advertisement/Scanning

- Advertisements happen at set intervals.
  - (advertising channels selected not to interfere with WiFi).
- Scanners make sure they are listening regularly on the advertising channels and collect the advertisements.
- Latency generated by time between scanning and advertising.

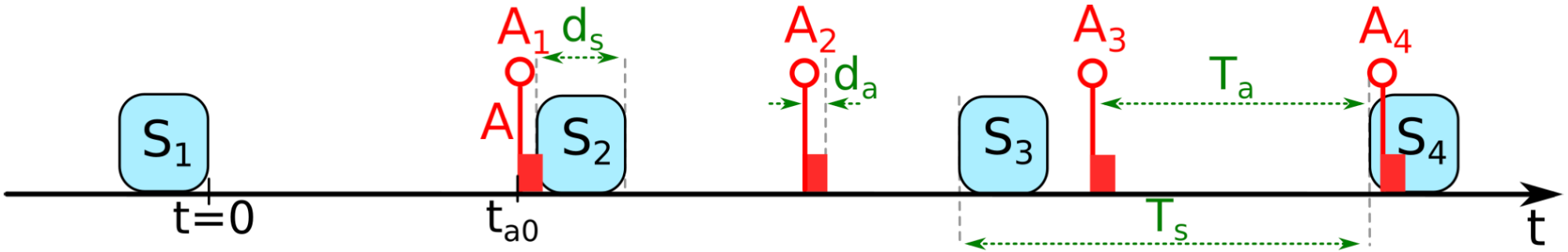


Figure from P. Kindt, M. Saur, M. Balszun and S. Chakraborty, "Neighbor Discovery Latency in BLE-Like Protocols" in IEEE Transactions on Mobile Computing, vol. 17, no. 03, pp. 617-631, 2018.

Contacts: what is important to detect?

- Depends on the application…but technology could detect:
    - Duration
    - Distance
    - Frequency
    - Angle/position
    - Location/context
- Issues
    - Interference/objects impact on signal
    - Line of sight/aerosol properties (wind)

Contact detection

- Can be done with various radios in theory
  - GPS only good outdoor
  - BLE low energy and point to point
  - WiFi less precise and more energy consuming
  - RFID technology: lower range, requires dedicated devices
- Some of these systems (WiFi and RFID) could be infrastructure-based or infrastructureless.

Application 1: Use of Space and Office Analytics

- Use of space and interaction in offices and teams.
- Applications in wellbeing, stress monitoring and group dynamics.

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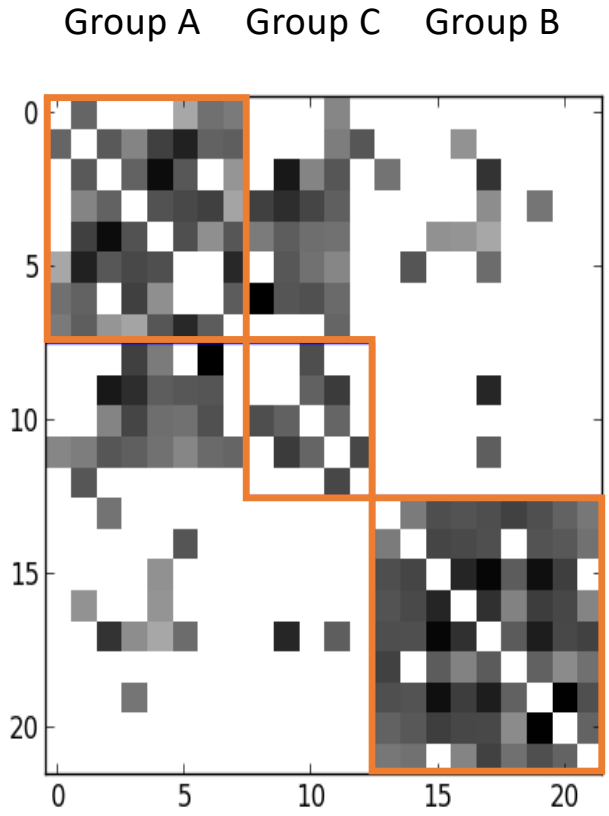
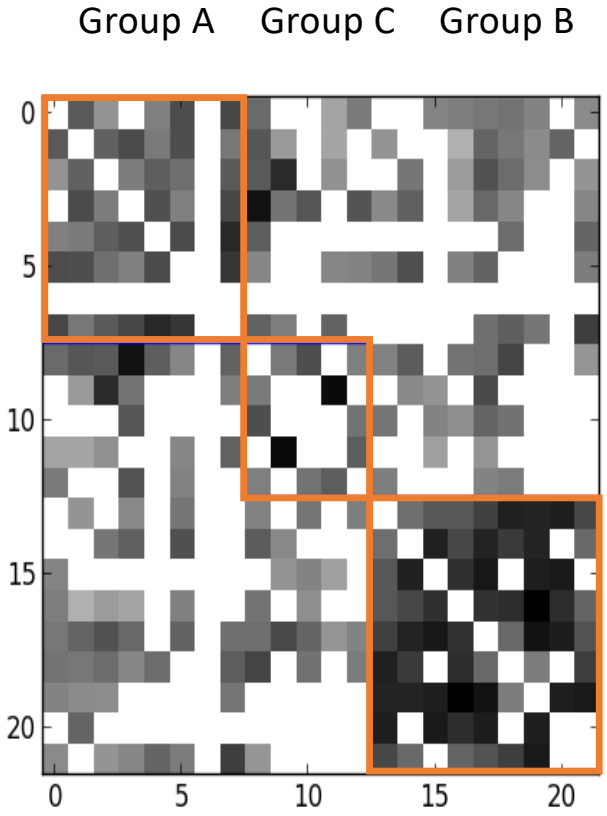
Office Contacts

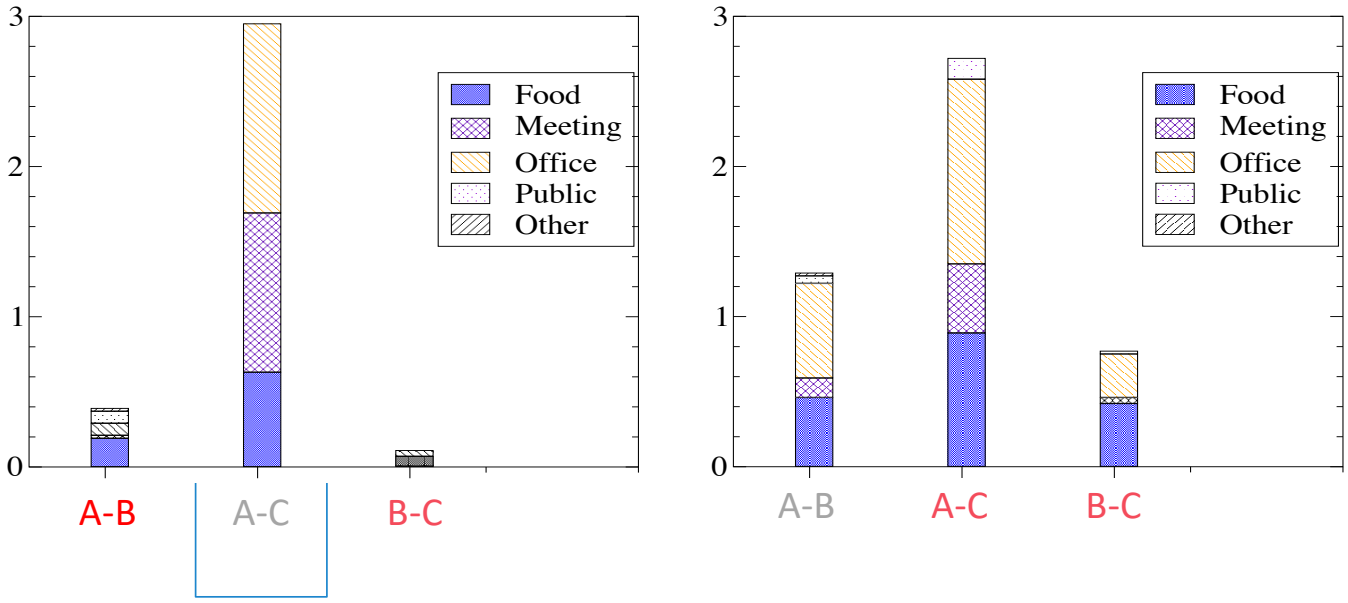


Old building



New building

Office Contacts: Floors



Application 2: Digital Contact Tracing

- Ability to trace the human contacts of a person who has revealed to be infected by a disease.

- Issues related to
  - What distance to use?
  - How long should these people be in contact for?
  - Facing each others?
  - Indoor/outdoor
  - …

Epidemiology

- Epidemiologists have prepared models for various types of epidemics
- Most basic are Susceptible/Infected/Susceptible (SIS) and Susceptible/Infected/Recovered (SIR)

- Parameters of digital contact tracing need to emulate “disease infectivity”

SIR Model

$$\begin{cases} \frac{dS}{dt} = -\frac{\beta IS}{N}, \\ \frac{dI}{dt} = \frac{\beta IS}{N} - \gamma I, \\ \frac{dR}{dt} = \gamma I, \end{cases}$$

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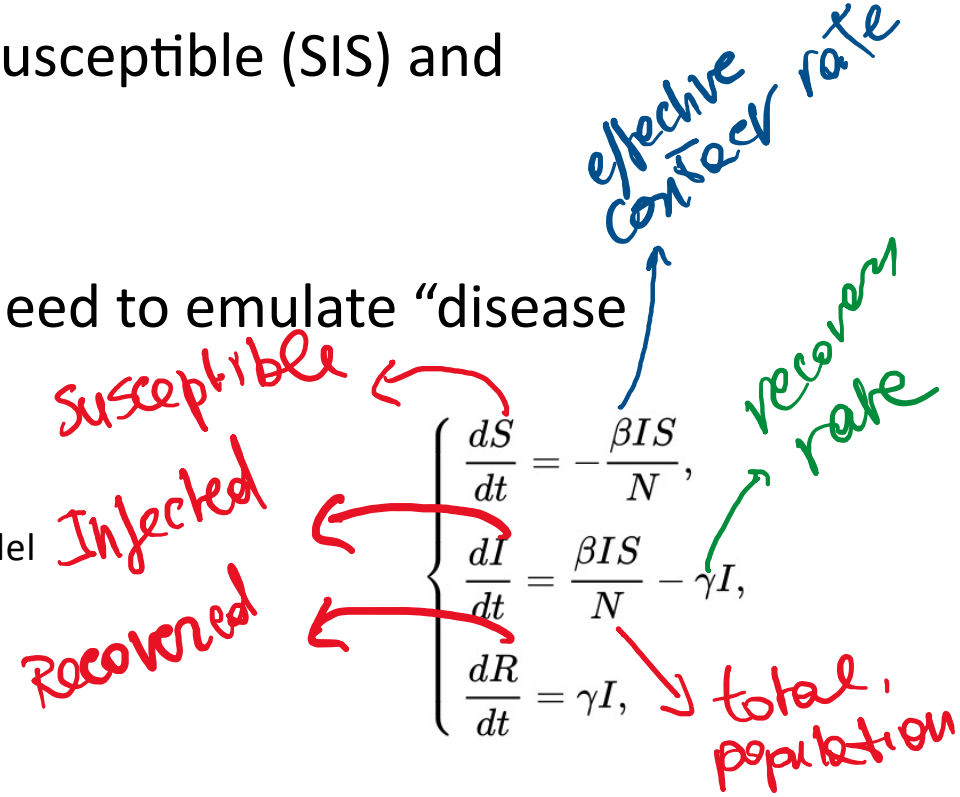

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Basics of Digital Contact Tracing

- Phases of contact tracing
  - Contact Logging
  - Infected/contact matching
  - Notification

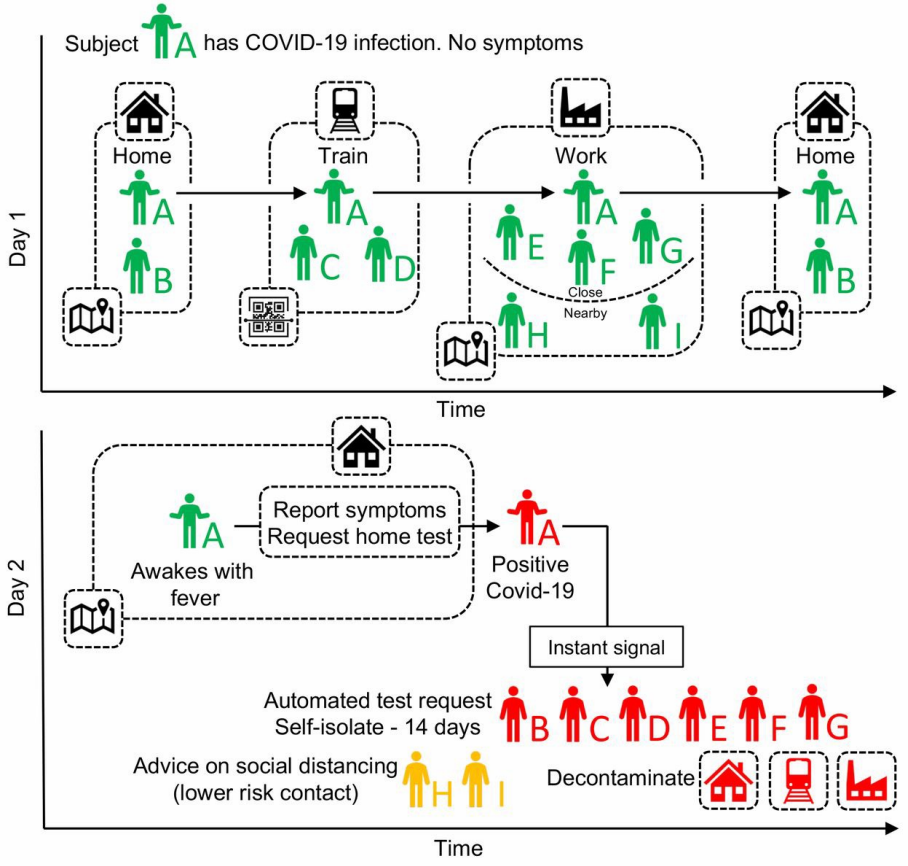

Figure from L. Ferretti, C. Wymant, M Kendall, L. Zhao, A. Nurtay, L. Abeler-Dörner, M. Parker, D. Bonsall, C. Fraser, (2020-03-31). "Quantifying SARS-CoV-2 transmission suggests epidemic control with digital contact tracing" (archived at the Wayback Machine). Science.

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Digital Contact Logging

- Phone BLE scans periodically for contacts at certain distance.
  - Which? E.g. <2 meters.
  - How is distance estimated:
    - Receiver signal strength indicator (RSSI)
    - Affected by obstacles…
    - What is the right threshold for COVID infection?
- Duration of this contact is also important!

Centralized vs Distributed Logging/Matching

- Basic:
  - Send all contact details to central server.
  - Central health authority does the matching with reported infected individuals.

- Ephemeral Identifiers:
  - Even if the central server does the matching with infected individuals, clients use a non identifiable token in the discovery process.
  - Tokens can be
    - just uploaded to central server who matches.
    - Or kept local and clients do the matching versus a central list of infected tokens.

Decentralized Privacy-Preserving Proximity Tracing DP-3T

- A decentralized protocol using ephemeral ID (EphID).
- Google/Apple adopted the model in their Exposure Notification project.

- EphIDs are 16 bytes. Never transmitted to servers.
  - Generated with a secret key changed daily.

- Two phases:
  - Tracking/logging.
  - Reporting.

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DP-3T Phases

- Tracking/Logging
  - Uses BLE adverting and scanning to send/receive EphIDs.
  - Receiver logs EphID with timestamp and signal strength.

- Reporting
  - Central Health Authority (CHA) confirms a client infection (through a code): client can then submit a report.
  - Client uploads the secret key for the day of infection and other clients can generate the same EphIDs locally for that day and look for matches in their log.
  - Server never sees the contacts.

Pros and Cons

- False positives: Digital solutions need to calibrate parameters and it is hard.
- False negatives: not catching true infected could be an issue…
- Epidemiology modelling: trade offs of storing contacts on server or not.

AirTags (and equivalent)

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How do they work?

- Airtags are “bound” to a specific phone (with an ID).
- Emit a BLE advert every X seconds (for all its lifetime).
- (Any) Phones and laptops can listen to these adverts and push them up to the vendors (“Find My”) network, after attaching its GPS position to the message.
- Only the owner’s phone can (with the ID) find the device message in the “Find My” network and therefore find its GPS position.

Issues

- Privacy: someone could place a tag on your belongings
  - Solution: now vendors notify you if you are close to a tag which is not paired with your device.

- These devices have started being used as “tags” for precious things but these devices per se do not have GPS so the retrieval can only work in a dense environment of phones/laptops etc.

Questions