Mobile Health

Radios, Bluetooth and Contact Tracing

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Radios

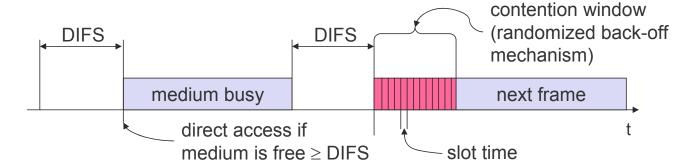
- Wearable/mobile device sensors have multiple radios which are used to detect presence in a location as well as contact.
 - Global Positioning System
 - Bluetooth
 - WiFi
 - Cellular
 - RFID
 - ...
- Technologies differ broadly in range, architecture and energy efficiency



WiFi Radio (802.11)

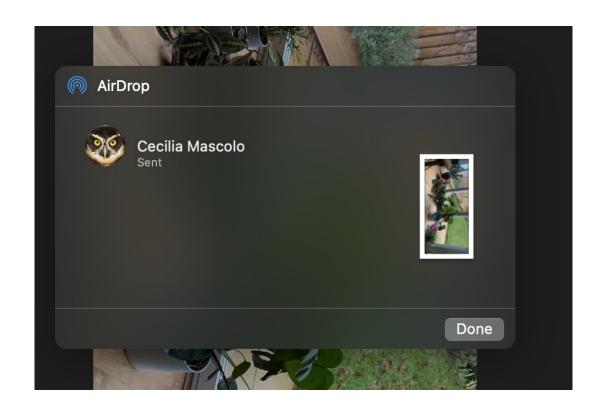
- Standards for communication for local area networks
- Client/server and peer to peer modes
- 11 Mbps to 20 Gbps
- Communication over frequency channels (some multiplexing at various levels, spatial, coding, time too).

 MAC layers support carrier sense multiple access with collision avoidance (CSMA/CA)





Low range ad hoc connectivity





Bluetooth Low Energy (BLE)

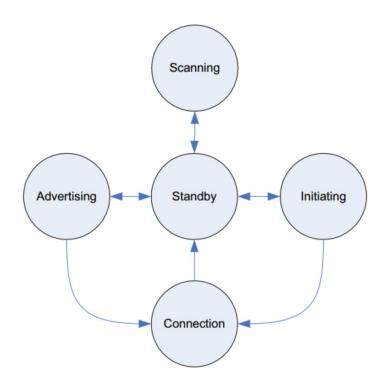


- Low connectivity range
- Low energy consumption
- 2.4 GHz band
- Transmission rate 1Mbps (going on 2Mbps)
- 40 channels separated by 2MHz (3 advertising channels)
- Central (e.g. Phones) and Peripheral Devices



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.

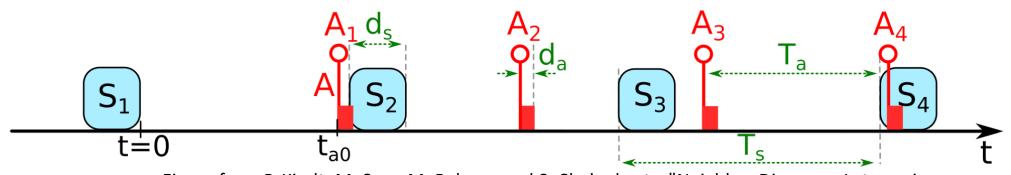




Figure from P. Kindt, M. Saur, M. Balszun and S. Chakraborty, "Neighbor Discovery Latency in BLE-Like Protocols" in IEEE Transactions on Mobile Computing, vol. 17, no. 03, pp. 617-631, 2018.

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



Application 1: Use of Space and Office Analytics

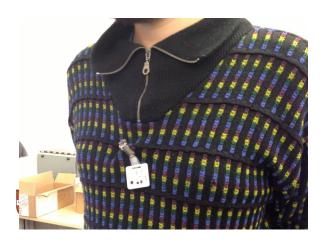
- Use of space and interaction in offices and teams.
- Applications in wellbeing, stress monitoring and group dynamics.

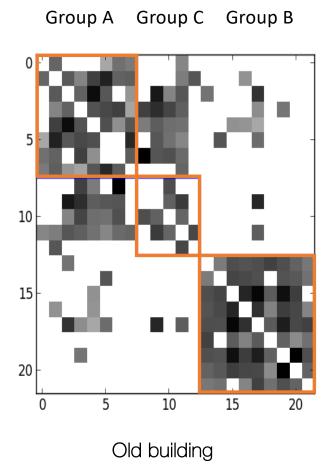


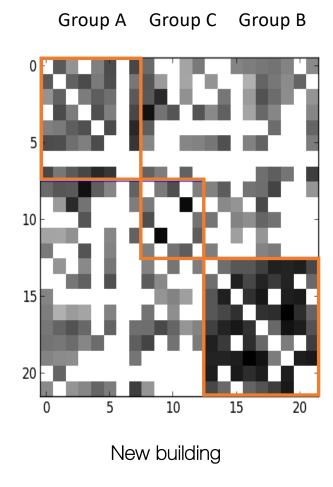


Office Contacts

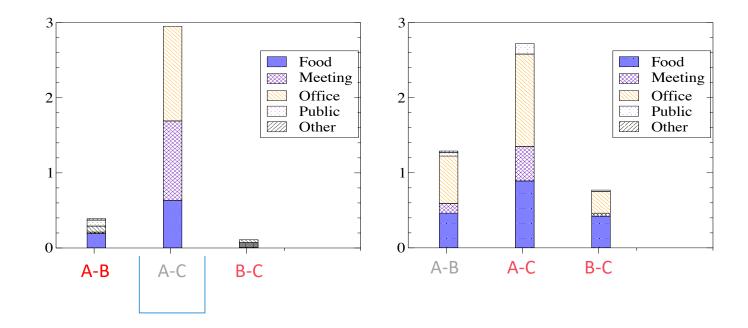








Office Contacts: Floors





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

$$\left\{ egin{aligned} rac{dS}{dt} &= -rac{eta IS}{N}, \ rac{dI}{dt} &= rac{eta IS}{N} - \gamma I, \ rac{dR}{dt} &= \gamma I, \end{aligned}
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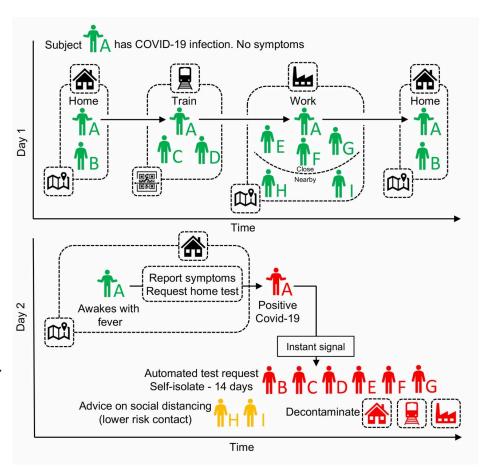


Basics of Digital Contact Tracing

- 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.





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?





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.





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.
- Epidemiology modelling: trade offs of storing contacts on server or not.



Questions

