COVID-19 Infection Progression

Index Case

- Exposure
- Incubation
- Symptom Onset
- Infectious
- Recovery

Infected Contact

- Index Exposure
- Infectious
- Recovery

0 5 days 10 days 15 days 20 days 25 days
Goal: Find this person before they might infect others

- Identify “contacts” that could have infected this person (reverse)
- Identify “contacts” that this person could infect (forward)
Contact Tracing

**Contact tracing** is an epidemiological technique used to identify people who have had “contact” with an infected person.

- Traditional uses:
  - Tuberculosis (2.9 cases / 100k people, > 900 cases / 100k for COVID-19†)
  - Smallpox
  - Sexually transmitted diseases

Contact tracing can help inform public health interventions to slow virus transmission.

[https://www.cdc.gov/mmwr/volumes/69/wr/mm6915e4.htm](https://www.cdc.gov/mmwr/volumes/69/wr/mm6915e4.htm)
Contact Tracing Tools

• Prior to COVID-19, contact tracing was primarily a manual process
• Primarily used for diseases with longer temporal characteristics

Public Health Contact Tracing Tools

Challenges
• Index case has to remember who they were in contact with, where they were
• Labor intensive and time consuming
• Increased risk of data errors
• Difficult to apply analytics
• Does not scale to need
• Need to know identifying information for contacts

Advanced contact tracing tools are urgently needed to handle COVID-19
Animation Video:
https://www.youtube.com/watch?v=yuXzAh4sINw
Likely Late Summer Scenario in a U.S. State

1. Contact Detection
   - Updated Apple & Google OS w/BT contact tracing built-in
   - State-acquired and A|G-approved app for user interface

2. COVID-19 Test Confirmed Positive
   - Database of Anonymized Contacts
     - State Dept of Health Virtual Community Tracing Center
     - Chirp Log:
       - Bluetooth Chirp Records
     - Manual Contacts Records
     - Manual Notification

3. Exposure Query & Notification
   - State-acquired app will provide tailored instruction to contacts
   - Symptom check
   - Test
   - Self Quarantine
   - Contacts

4. Contact Actions
   - iPhone or Android
     - Updated Apple & Google OS w/BT contact tracing built-in
     - State-acquired and A|G-approved app for user interface
   - State-acquired and A|G-approved app
   - State-acquired and A|G-approved app for user interface
Public health authorities define alert region
Engineers try to implement it accurately

Notional Alert Region

Alert!

Range

Exposure Time

0m 1m 2m 3m 4m

1min

10min

30min

1hr

8hrs

Hug

Handshake

Same Table @ School

Side-by-Side @ Coffee Shop

Subway, One Stop, Same Car

Same Classroom

No Alert
Assessing TC4TL Systems

- Probability of False Positive (Leads to applying effort & treatment unnecessarily to a healthy person)
- Probability of False Negative (a.k.a. Miss) (Leads to withholding effort & treatment from a sick person)

<table>
<thead>
<tr>
<th>Probability of False Positive</th>
<th>Probability of False Negative</th>
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<tbody>
<tr>
<td>0.01%</td>
<td>99%</td>
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<tr>
<td>0.1%</td>
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<td>1%</td>
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<tr>
<td>10%</td>
<td>50%</td>
</tr>
<tr>
<td>99%</td>
<td>0.01%</td>
</tr>
</tbody>
</table>

- "Flip a Coin"  
- System A  
- System B  
- Everybody Stay Home  
- Do Nothing

- Want to give public health authorities freedom to pick from a range of operating points
- If we can estimate \( \text{Pr(pos)} \), \( \text{Pr(neg)} \), \( \text{Cost(FN)} \), \( \text{Cost(FP)} \), we can find the lowest-cost operating point on the DET* curve

Empirically measure RSSI vs range for many conditions
- Phone orientation
- Location of phone
- Phone model
- Multipath environment

Phone conditions lead to 20dB (100x) variation in RSSI at fixed distance
Preliminary TC4TL Performance**

- 1 of 6, Agnostic: 30 min duration, phone wakes up 6 times, one attenuation per wake up period, no info re phone carriage

- M of 24, Agnostic: 30 min duration, phone wakes up 6 times, 4 samples per wake up period, no info re phone carriage

- 1 of 6, Cognitive: Same as 1 of 6 above except threshold specific to perfect phone carriage information

- M of 24, Cognitive: Same as M of 24 above except threshold specific to perfect phone carriage information

- Data: “Range-Angle” data set. Collected at distances of 3 to 15 feet at every 45-degree angle for a variety of conditions (e.g. phone in pocket, hand, purse, bag, etc.)

Better signal processing with additional metadata sent with chirp (no additional power, storage) can reduce EER from ~40% to ~15% EER


Advanced Proximity Testing

Robotic Testing in the ASDF

Mannequins on TurtleBots

Bluetooth Scanning Apps
- LL custom
- 3rd party

MIT LL @ Waypoint Robotics

ASDF = MIT LL Autonomous System Development Facility (Group 76)
Animation Video: "Robot Dance" https://youtu.be/1F6TEvpy5g0
PACT Public Data Repository

https://mitll.github.io/PACT/

PACT Datasets and Evaluation

Our mission is to aggregate datasets and provide an evaluation platform in support of the PACT mission statement.

What is PACT?

To learn more about Private Automated Contact Tracing (PACT), please visit PACT's Website.

Submit a Dataset Submit a Solution Participate in Data Collection

Contact Us

To contact the PACT Datasets and Evaluation team, please submit an issue on Github using the Question tag.

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Evaluations: NIST TC4TL Challenge

https://www.nist.gov/itl/iad/mig/nist-tc4tl-challenge

- Explore promising new ideas in TC4TL detection using BLE signal
- Support the development of advanced technologies incorporating these ideas
- Measure and calibrate the performance of the state-of-the-art TC4TL detectors
User Interfaces

Mobile Phone App

- For individual citizens
- Alerts user of potential exposure
- Turns exposure tracing on and off

Epidemiology Dashboards

- For public health professionals
- Helps contact tracers manage cases
- Provides summary epidemiological metrics
PACT Accomplishments

ImPACT 2020 Conference

- Welcome remarks by MA Gov Baker
- Technical exchange of ideas
- 500+ global participants

Exposure notification system for iOS and Android

- A|G ENS consistent with the PACT protocol
- Providing technical advice to Apple and Google
  - “Too close for too long” detector design
  - Laboratory RF measurements and analysis
- Weekly meetings with the A|G technical teams

- Trusted technical advisor to US CDC
- Trusted technical advisor to Massachusetts and Pennsylvania
Advanced Concepts

Improved Inter-Device Ranging

**Ultra wideband (G39’s LLDART)**

**Ultrasound**

“Wearables” and Tokens

**Smart watches**

**RF tokens & bands**

Apple | Google Subsystem Compatibility

- **Bluetooth Chirps**
- **Key Exchange**
- **Custom Hardware**

Trustless Servers and Data Stores

LLDART = Low-cost Localization using Distributed Adaptable Response Transponders
• Contact tracing combined with public health action, such as testing and quarantining, will help reduce virus spread

• Automated contact tracing can supplement manual efforts
  – Automation of contact analysis
  – Automatic detection of high-risk exposure events

• PACT seeks to advance the state-of-the-art in private automated contact tracing solutions

• Significant opportunities for future technical innovation exist

PACT serves as trusted technical advisor to federal, state and local public health authorities (PHAs) and as a convening center for collecting and sharing data and best practices for private automated contact tracing