Massachusetts Institute of Technology

PACT

PACT: Private Automated Contact Tracing

7 October 2020

Marc Zissman, PhD
MIT Lincoln Laboratory
MAZ@LL.MIT.EDU

CSAIL

MASSACHUSETTS GENERAL HOSPITAL GLOBAL HEALTH

LINCOLN LABORATORY MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Protocol Definition Working Group

CSAIL

LINCOLN LABORATORY MASSACHUSETTS INSTITUTE OF TECHNOLOGY

mit media lab

BOSTON UNIVERSITY

WEIZMANN INSTITUTE OF SCIENCE

COVID SafePaths

BROWN

Sponsors

DARPA

CDC CENTERS FOR DISEASE CONTROL AND PREVENTION

IBM Research

Data Collection Coalition

ARL DISCOVER INNOVATE TRANSITION

NREC EXPERIENCE · EXPERTISE · EXCELLENCE

Carnegie Mellon University

DRAPER LABORATORY

Lawrence Livermore National Laboratory

masssrobotics

LINCOLN LABORATORY MASSACHUSETTS INSTITUTE OF TECHNOLOGY

MITRE

Northeastern

Qualcomm

Raytheon BBN Technologies

Sandia National Laboratories

Government Digital Services, Singapore

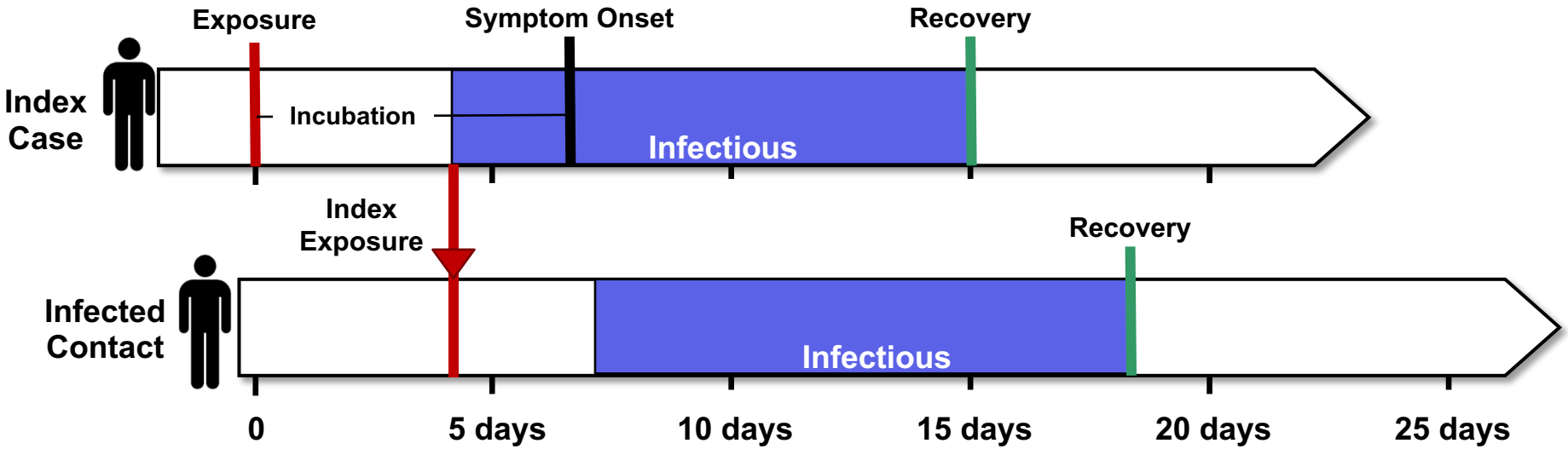
str SYSTEMS & TECHNOLOGY RESEARCH

WPI

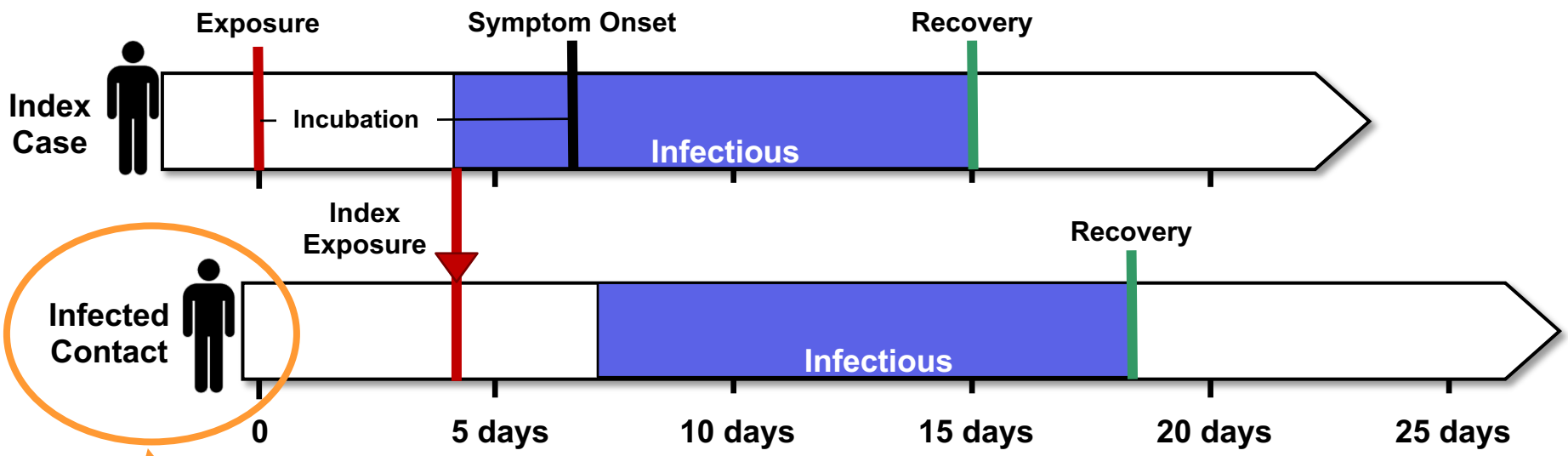
WAYPOINT ROBOTICS

Massachusetts Institute of Technology

COVID-19 Infection Progression



COVID-19 Infection Progression



Goal: Find this person *before* they might infect others

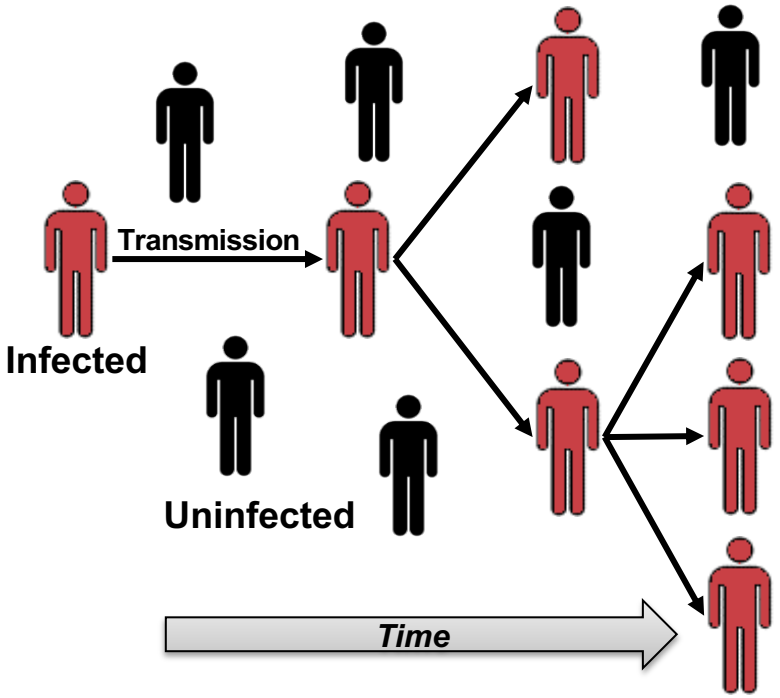
- **Identify "contacts" that could have infected this person (reverse)**
- **Identify "contacts" that this person could infect (forward)**

https://www.cdc.gov/coronavirus/2019-ncov/hcp/clinical-guidance-management-patients.html
The Incubation Period of Coronavirus Disease 2019 (COVID-19) From Publicly Reported Confirmed Cases: Estimation and Application
https://wwwnc.cdc.gov/eid/article/26/7/20-0282_article https://www.harvardmagazine.com/2020/05/r-nought
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7054855/ ; https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7121626/

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/tb/statistics/indicators/2018/incidence.htm for Massachusetts
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

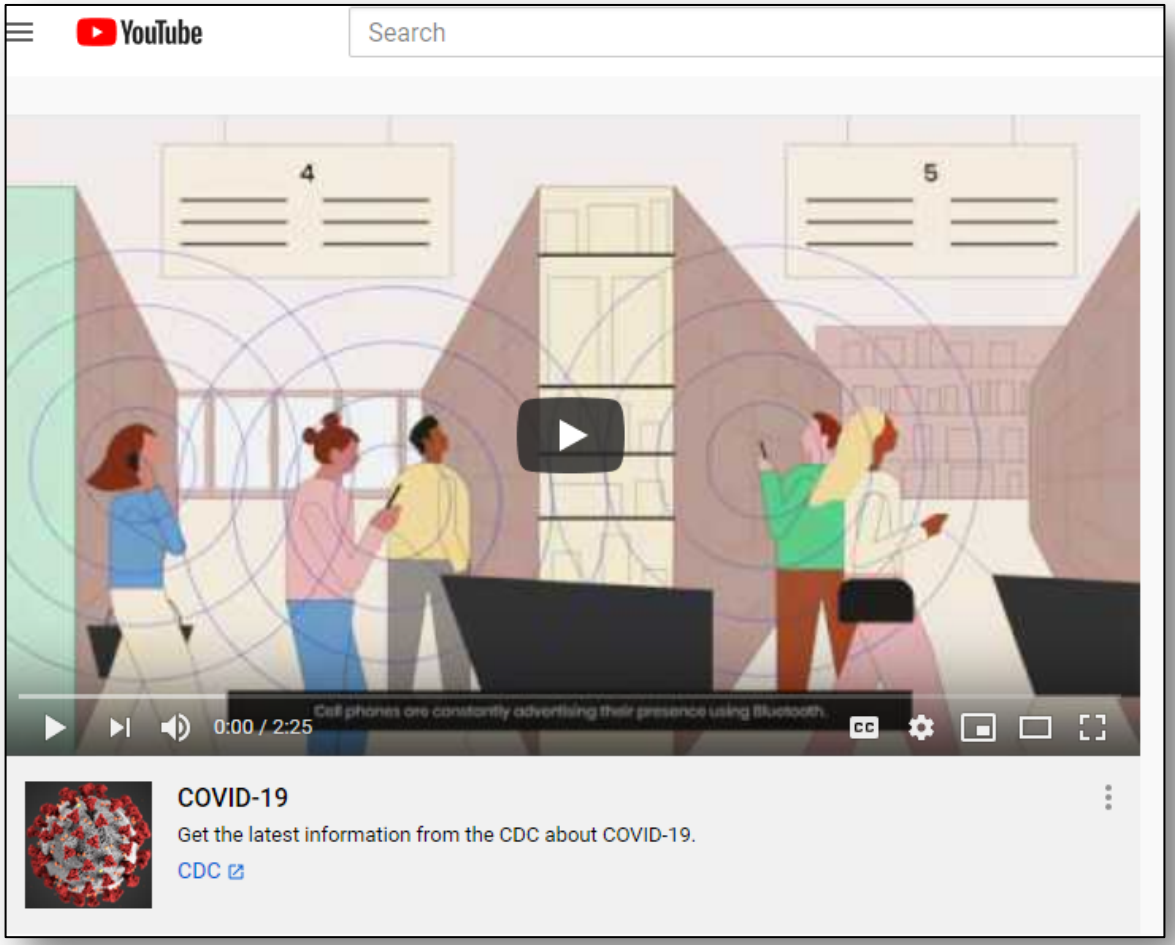
Public Health Contact Tracing Tools

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

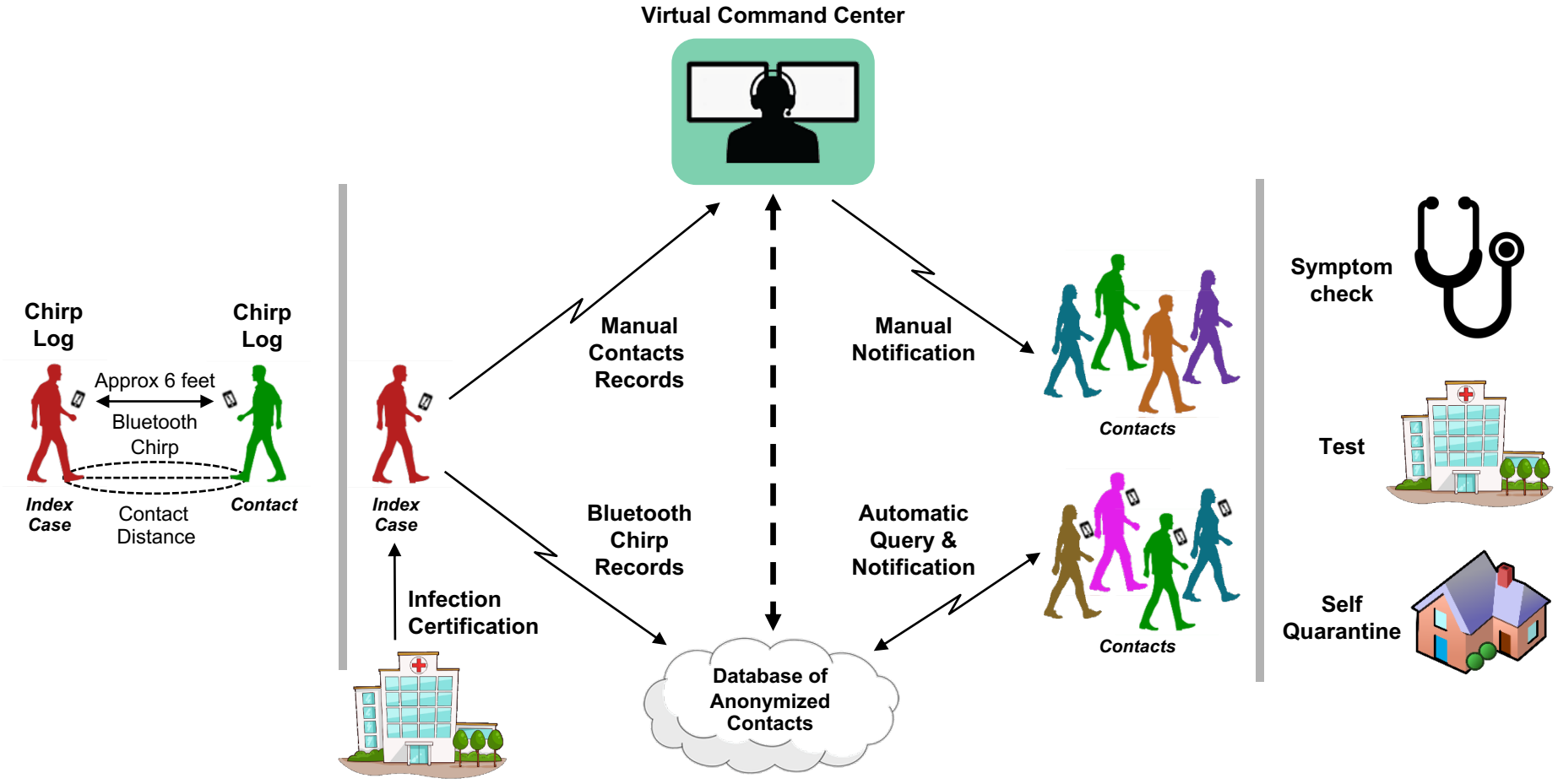
Advanced contact tracing tools are urgently needed to handle COVID-19

Animation Video



Animation Video:
https://www.youtube.com/watch?v=yuXzAh4sINw

General Approach



1 Contact Detection

2 COVID-19 Test Confirmed Positive

3 Exposure Query & Notification

4 Contact Actions

Massachusetts Institute of Technology

PACT Stack

Layer 3A: Public Health Interface

Major Challenges

- Integration into manual contact tracing systems
- Certification of infection
- Interoperability across public heath authorities
- Specifying "Too Close for Too Long" requirements
- Trustworthy systems to earn broad societal trust

Layer 3B: Individual Interface

Major Challenges

- Clear and local culture-appropriate opt-in instructions and explanation of privacy guarantees
- Simple functionality for reporting and certifying infection
- Simple functionality for notification of possible "too close for too long" contact and related instructions
- Integration with other public health functionality not directly PACT related

Layer 2: Private Cryptographic Protocol

Major Challenges

- Privacy preservation
- Chirp rollover frequency
- Reporting chirps sent vs chirps rec'd
- Mitigating threats posed by malicious parties

Layer 1: Proximity Measurement

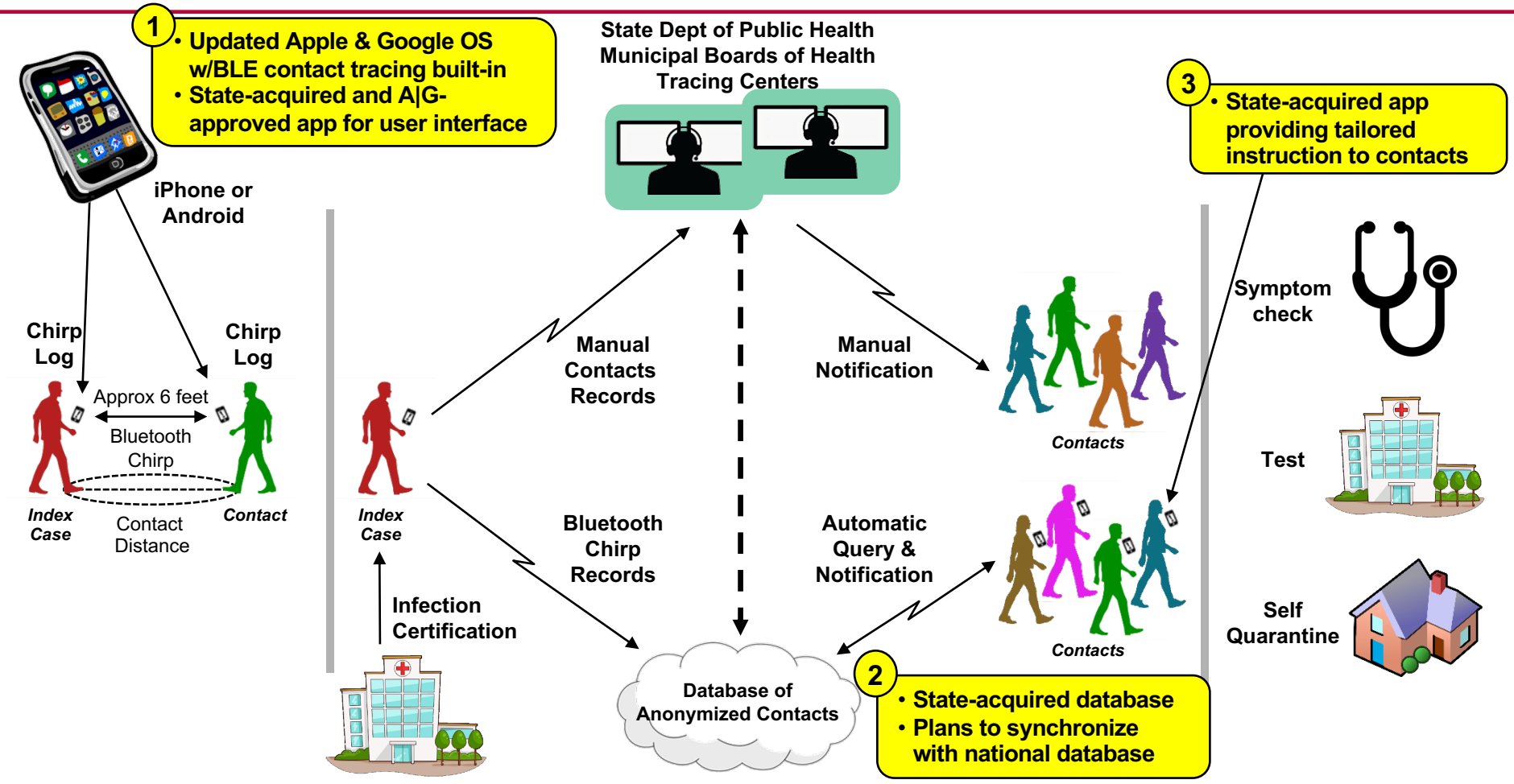
Major Challenges

- Bluetooth phenomenology & data collection
- Implementing & evaluating "Too Close for Too Long" analytic
- Android, iOS interoperability
- Operating system policy compliance
- Smartphone power constraints
- OS vs app functional decomposition
- Other signaling options, e.g. ultrasound and UWB

Massachusetts Institute of Technology

August 2020 Status in Leading U.S. States

PACT



1 Contact Detection

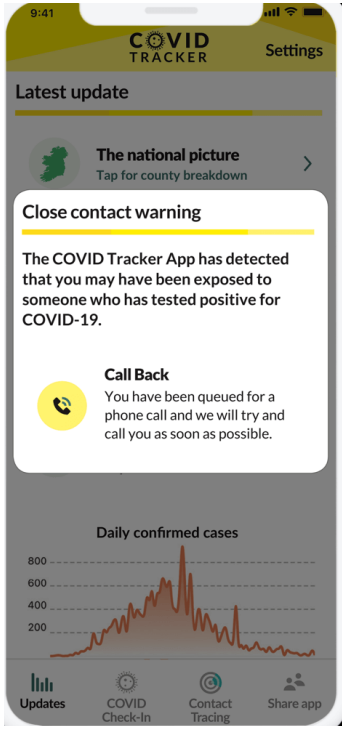
2 COVID-19 Test Confirmed Positive

3 Exposure Query & Notification

4 Contact Actions

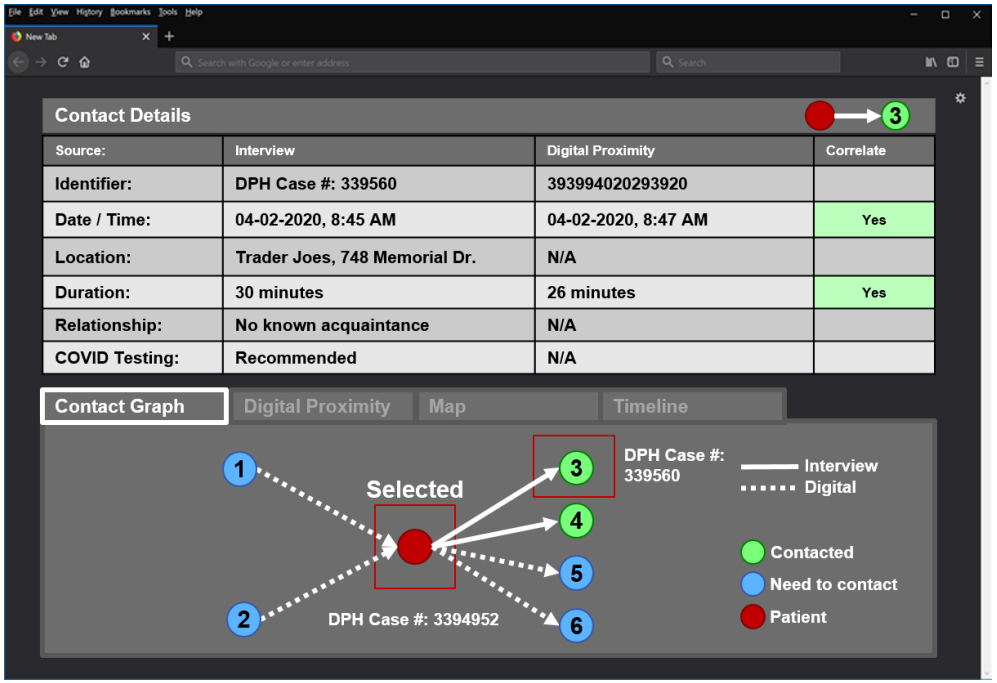
User Interfaces

Mobile Phone App*



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

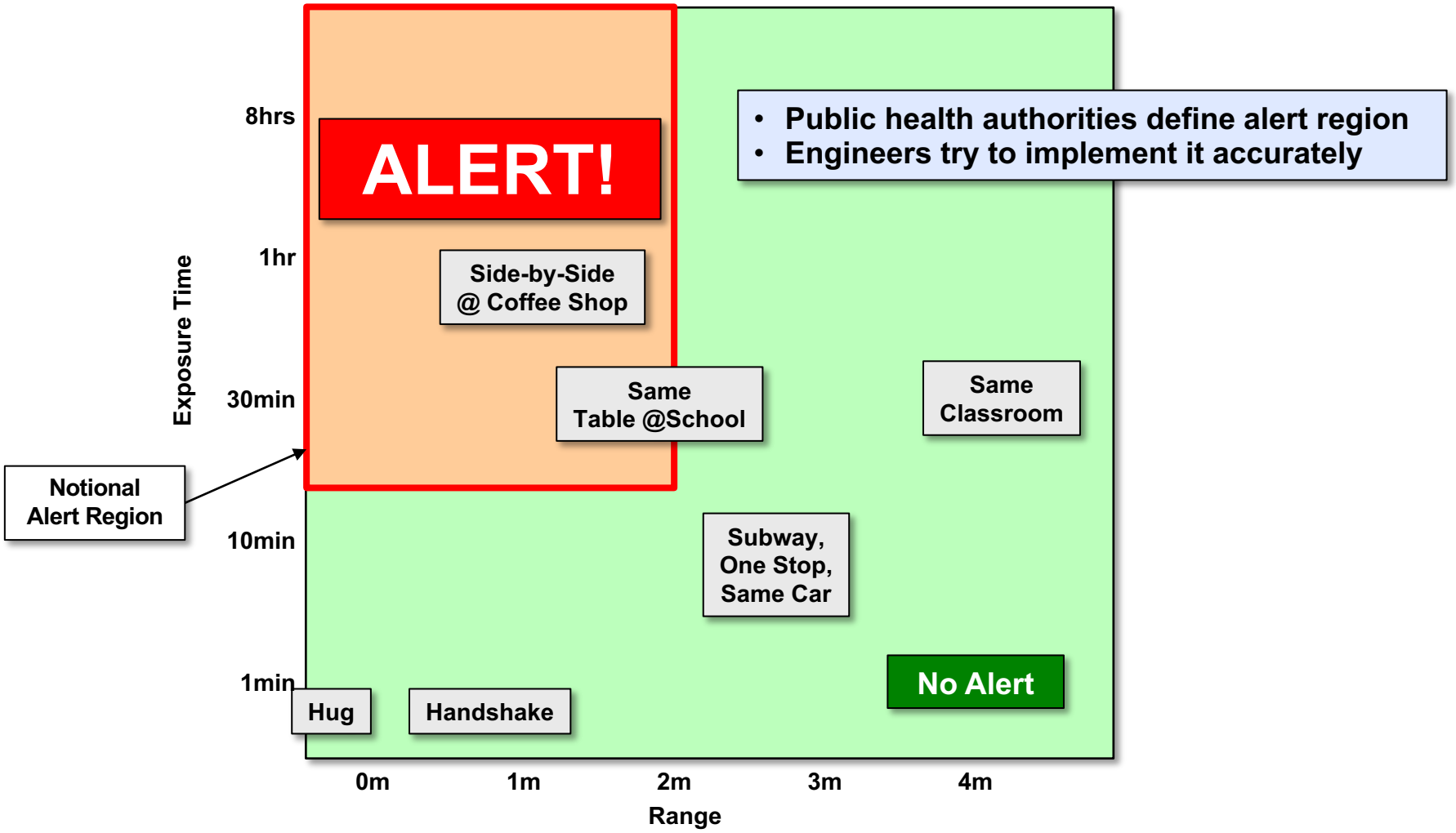
Epidemiology Dashboards



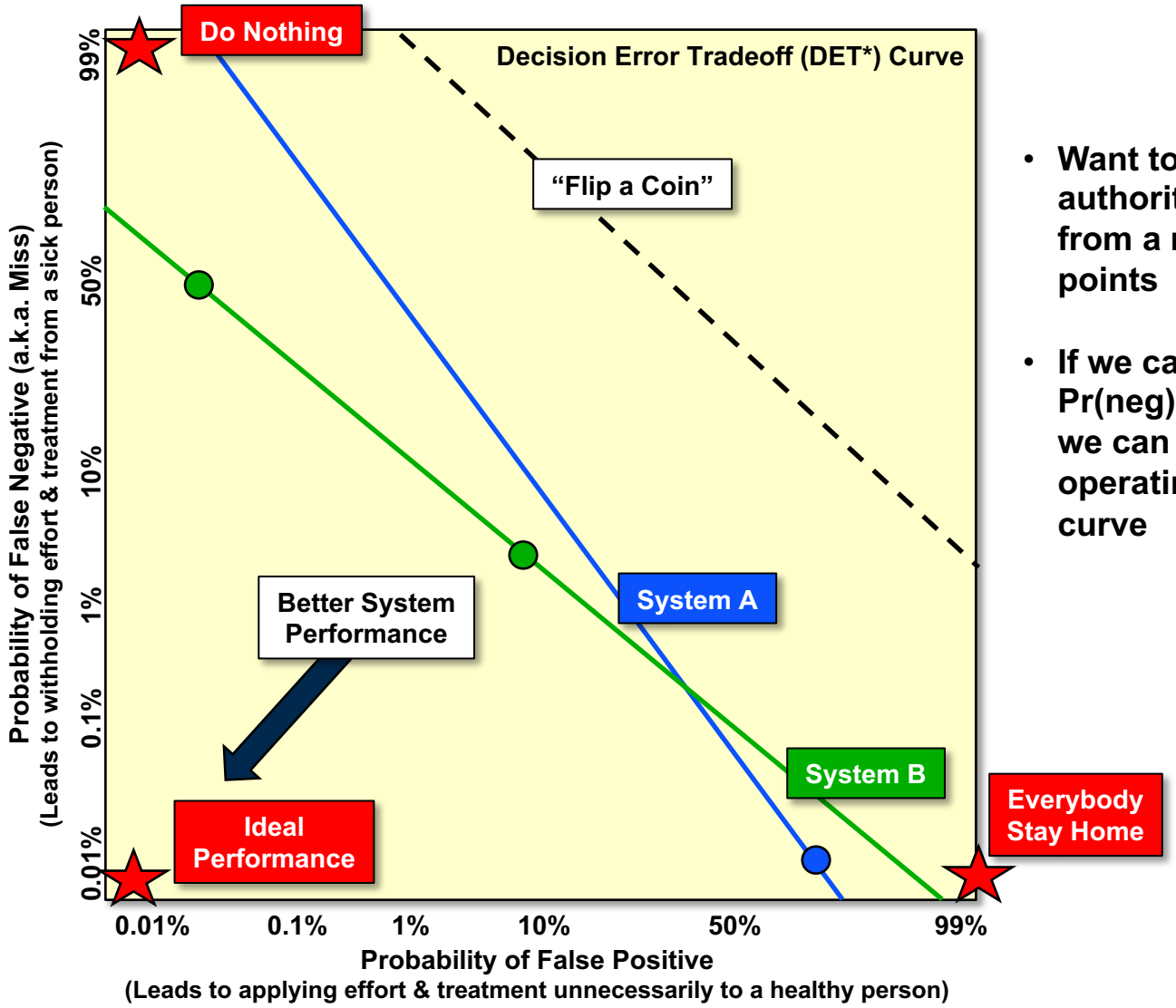
- For public health professionals
- Helps contact tracers manage cases
- Provides summary epidemiological metrics

Ireland “COVID Tracker” App built by NearForm

“Too Close for Too Long” – TC4TL



Assessing TC4TL Systems

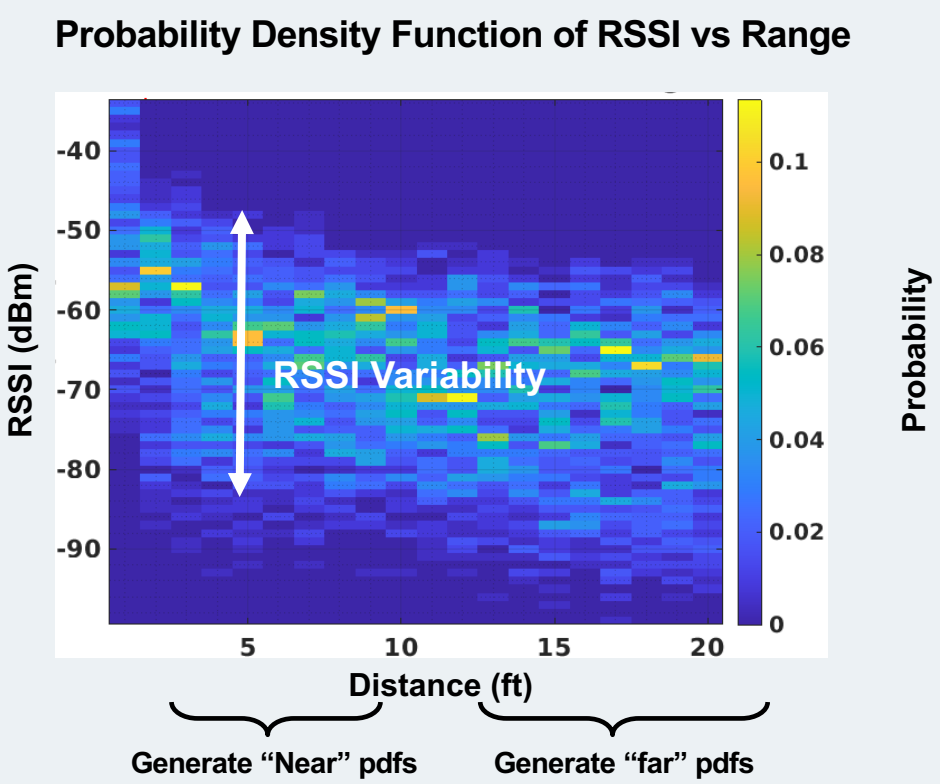


- Want to give public health authorities freedom to pick from a range of operating points
- If we can estimate Pr(pos), Pr(neg), Cost(FN), Cost(FP), we can find the lowest-cost operating point on the DET* curve

*A. Martin, A., G. Doddington, T. Kamm, M. Ordowski, and M. Przybocki. "The DET Curve in Assessment of Detection Task Performance", Proc. Eurospeech '97, Rhodes, Greece, September 1997, Vol. 4, pp. 1895-1898.

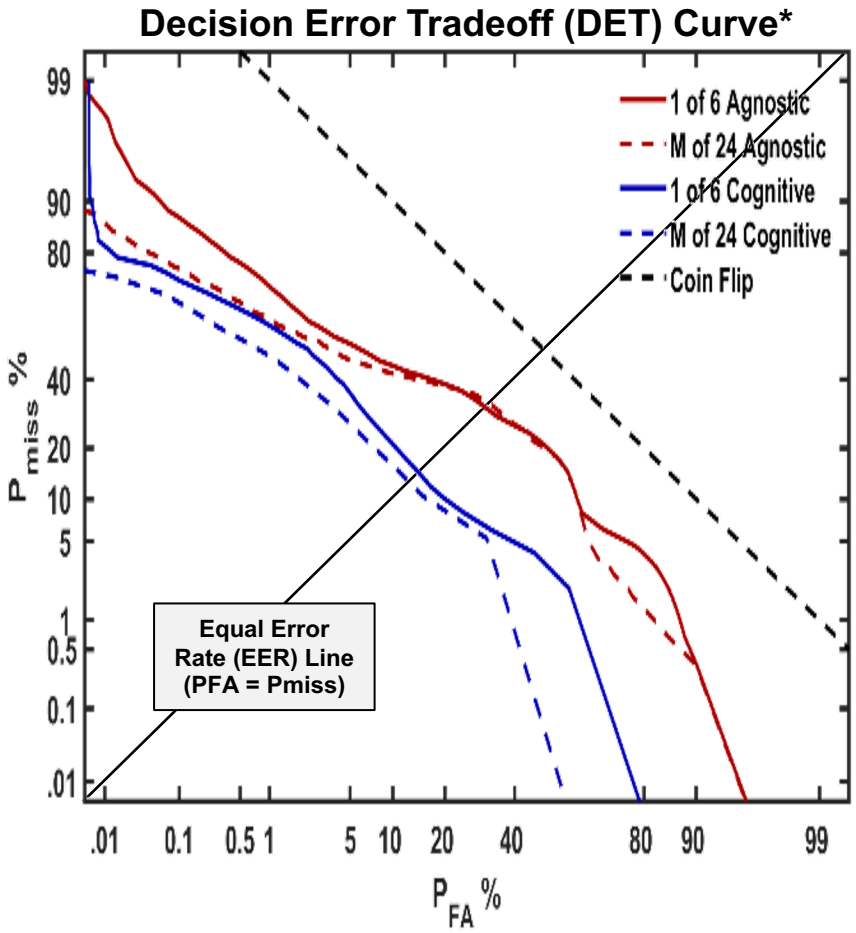
Initial Bluetooth Data Collection

- 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**



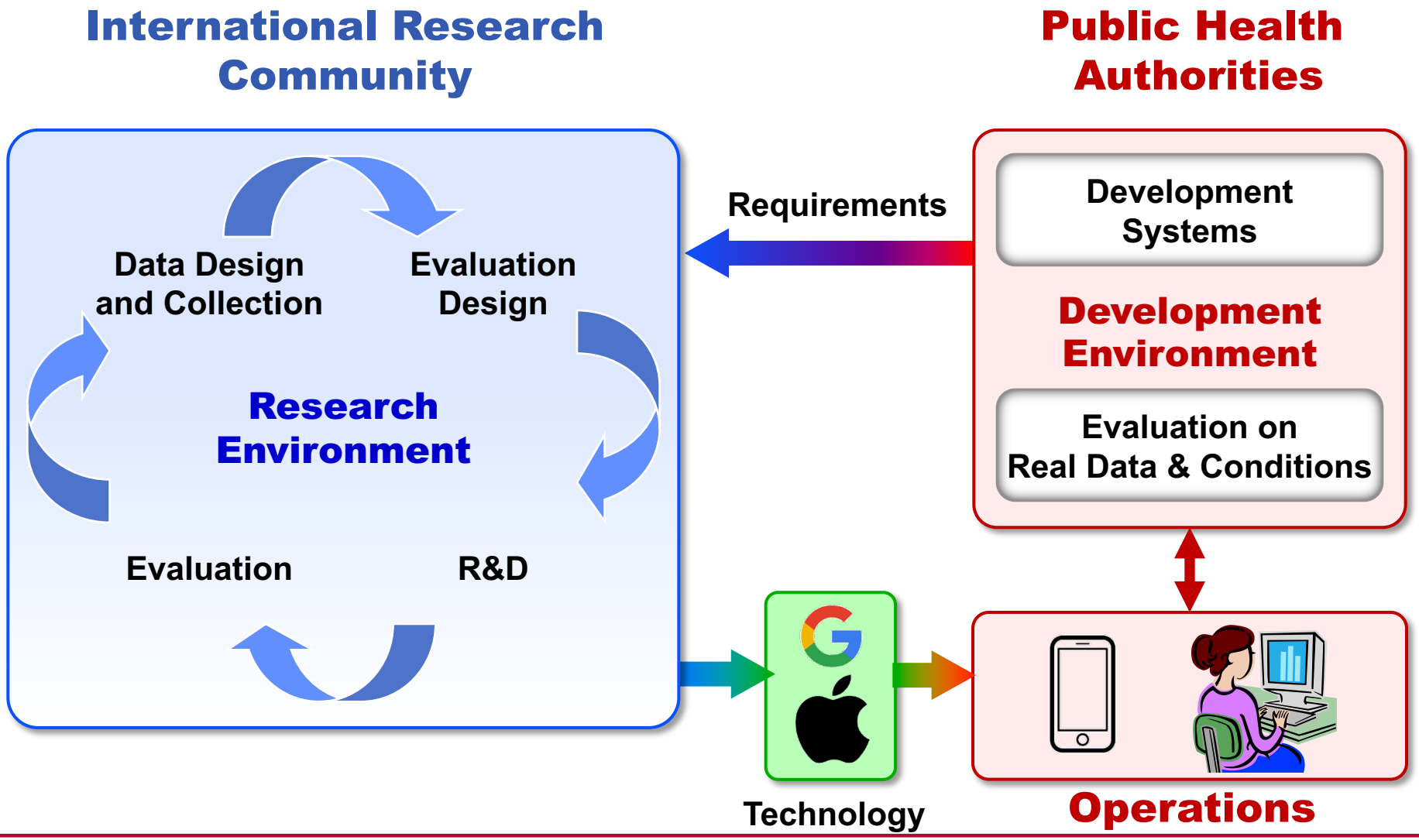
- 1 of 6, Agnostic: 30 min duration, phone wakes up 6 times, one attenuation per wake up period, no info re phone carriage
- M of 24, Agnostic: 30 min duration, phone wakes up 6 times, 4 samples per wake up period, no info re phone carriage
- 1 of 6, Cognitive: Same as 1 of 6 above except threshold specific 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

*A. Martin, A., G. Doddington, T. Kamm, M. Ordowski, and M. Przybocki. "The DET Curve in Assessment of Detection Task Performance", Proc. Eurospeech '97, Rhodes, Greece, September 1997, Vol. 4, pp. 1895-1898.

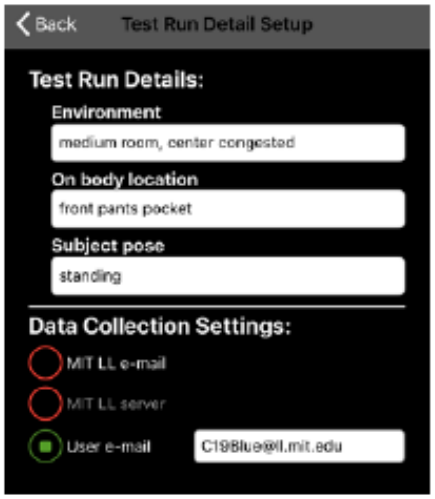
** G. F. Hatke et al. "Using BLE Signal Strength Estimation to Facilitate Contact Tracing for COVID-19" https://arxiv.org/abs/2006.15711

Data-Driven R&D

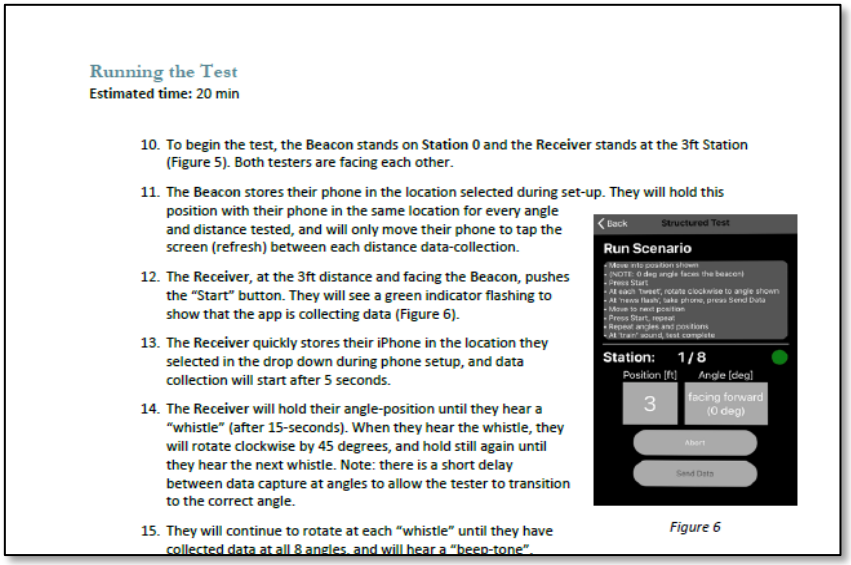


Data Collection Process

New app version



Detailed test protocol



Running the Test

Estimated time: 20 min

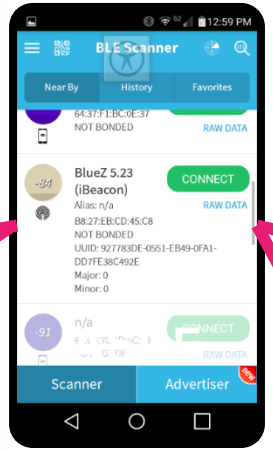
10. To begin the test, the Beacon stands on **Station 0** and the **Receiver** stands at the 3ft Station (Figure 5). Both testers are facing each other.
11. The Beacon stores their phone in the location selected during set-up. They will hold this position with their phone in the same location for every angle and distance tested, and will only move their phone to tap the screen (refresh) between each distance data-collection.
12. The Receiver, at the 3ft distance and facing the Beacon, pushes the "Start" button. They will see a green indicator flashing to show that the app is collecting data (Figure 6).
13. The Receiver quickly stores their iPhone in the location they selected in the drop down during phone setup, and data collection will start after 5 seconds.
14. The Receiver will hold their angle-position until they hear a "whistle" (after 15-seconds). When they hear the whistle, they will rotate clockwise by 45 degrees, and hold still again until they hear the next whistle. Note: there is a short delay between data capture at angles to allow the tester to transition to the correct angle.
15. They will continue to rotate at each "whistle" until they have collected data at all 8 angles, and will hear a "beep-tone".

Figure 6

- **Streamlined app nearing completion, will be available on TestFlight**
  - **BlueProx**
  - **Drop-down menus**
  - **Files to be emailed to an MIT address, will be uploaded to database**
- **Test protocol provides detailed instructions**
  - **Requires 2 iPhones**
  - **Measurements run through all azimuth angles and ranges**
- **Each test takes ~ 25 min**
- **Instruction to participate will be available the PACT data repository site:**
  - **https://mitll.github.io/PACT/index.html**

Robotic Data Collection

Robotic Testing in the ASDF



Bluetooth Scanning Apps

- **LL custom**
- **3rd party**

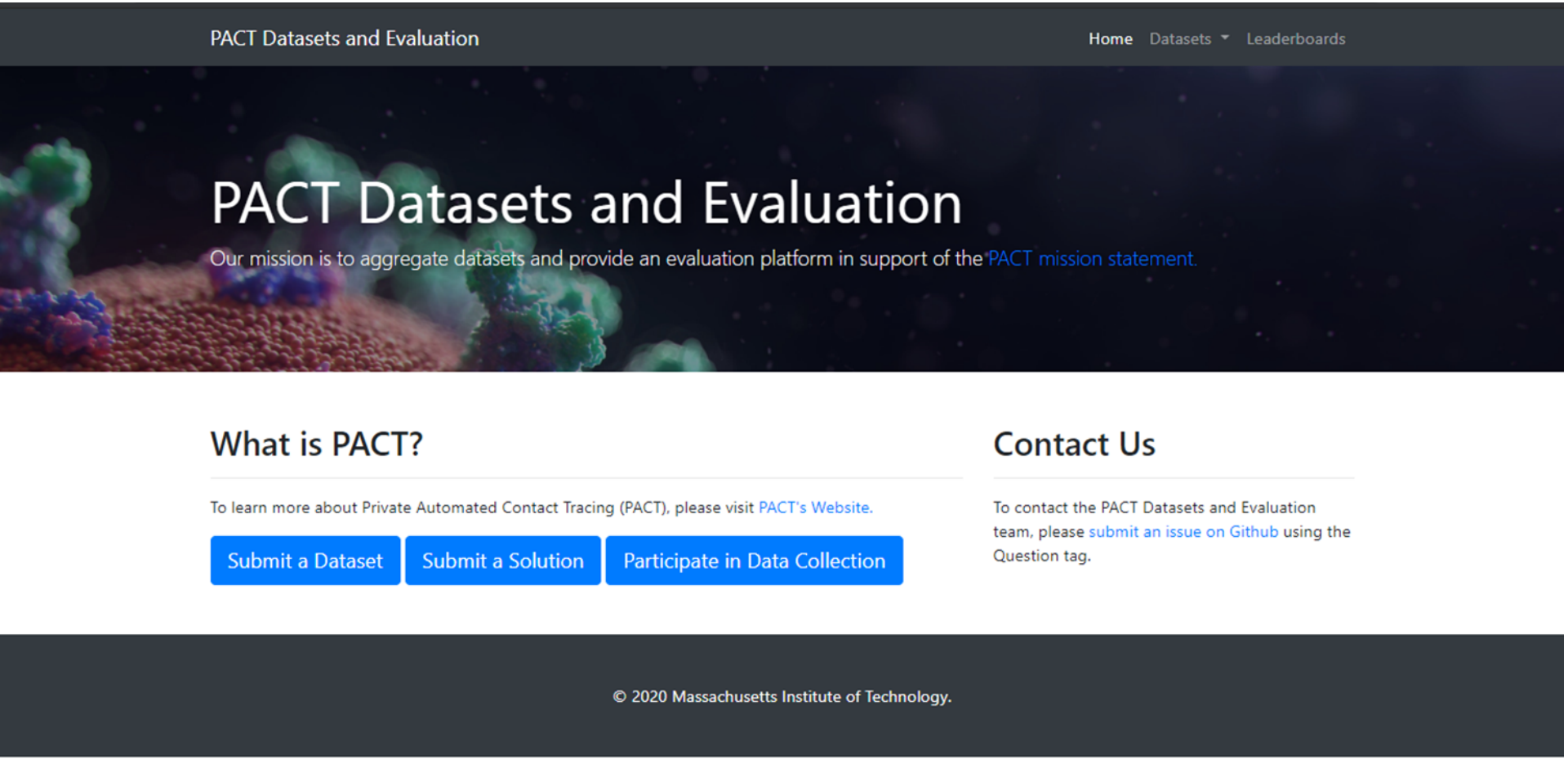
MIT LL @ Waypoint Robotics

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/



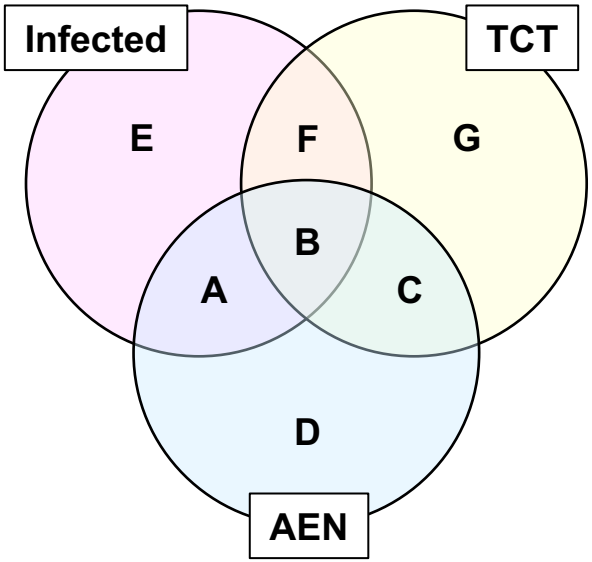
NIST TC4TL Challenge September 2020

National Institute of Standards and Technology
U.S. Department of Commerce

- **Explored promising new ideas in TC4TL detection using BLE signals**
- **Supported the development of advanced technologies incorporating these ideas**
- **Measured and calibrated the performance of the state-of-the-art TC4TL detectors**

https://www.nist.gov/itl/iad/mig/nist-tc4tl-challenge
https://tc4tlchallenge.nist.gov/

Assessment: The 3-Circle Venn Diagram



AEN: Automated exposure notification
TCT: Traditional contact tracing

- **Which problems are we trying to solve? E.g.**
  - **Find infected new contacts through AEN that TCT misses, i.e. maximize A**
  - **Make AEN sensitivity high, i.e. maximize (A+B)/(A+B+E+F)**
  - **Make AEN specificity high, i.e. maximize (A+B)/(A+B+C+D)**
  - **Find infected contacts through AEN that TCT also finds (i.e. B), but find them faster**
- **What else is required?**
  - **Rapid, accurate testing**
  - **Rapid, effective quarantine and isolation**
  - **Integration of AEN/TCT, testing and Q/I**
- **Hundreds of papers are modeling TCT (and AEN) efficacy**
  - **Real data are just becoming available**

PACT Highlights

ImPACT 2020 Conference

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

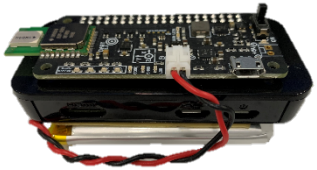
- Trusted technical advisor to US CDC
- Trusted technical advisor to Massachusetts and Pennsylvania

Exposure notification system for iOS and Android

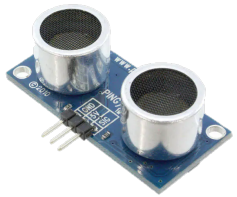
- A|G ENS consistent with the PACT protocol
- Providing technical advice to Apple and Google
  - "Too close for too long" detector design
  - Laboratory RF measurements and analysis
- Weekly meetings with the A|G technical teams

Advanced Concepts

Improved Inter-Device Ranging



Ultra wideband
(G39's LLDART)



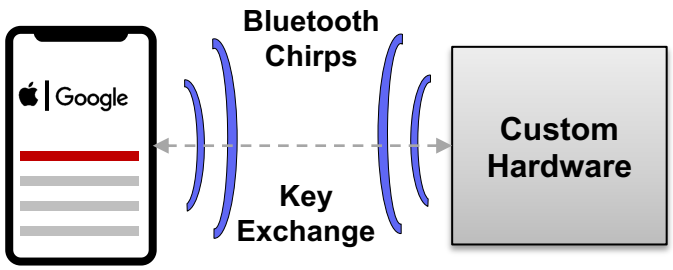
Ultrasound

"Wearables" and Tokens

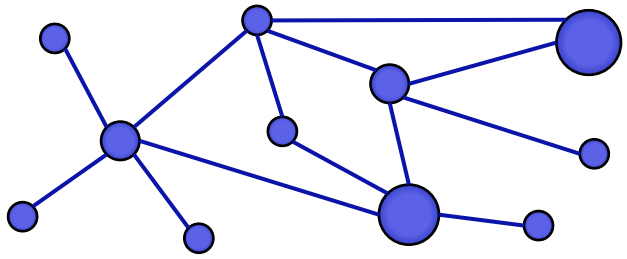
Smart watches

RF tokens &
bands

Apple | Google Subsystem Compatibility



Trustless Servers and Data Stores



LLDART = Low-cost Localization using Distributed Adaptable Response Transponders

Massachusetts Institute of Technology

PACT: Current Objectives

- **Layer 1 – Proximity measurement**
  - Collect and distribute data (including ground truth) publically, define and publish metrics, develop TC4TL analytics, support open NIST evaluations, repeat, improve
  - Report evaluation results publically and provide recommendations to Apple and Google
  - Consider, demonstrate and assess appropriateness of non-BLE signaling approaches, e.g. ultrasound, UWB
- **Layer 2 – Private cryptographic protocol**
  - Continue to monitor Apple and Google progress on their PACT-like protocol; exercise their APIs
  - Ensure that resulting protocol is indeed as private as possible
  - Improve algorithm as required, and make recommendations to Apple and Google
- **Layer 3A – Public health interface**
  - Help PHAs develop the architectures for the systems they are buying from industry
- **Layer 3B – Individual interface**
  - Work with PHAs to help define requirements for smartphone apps they are buying from industry
  - Help PHAs run pilots, assess results and scale to widespread deployment
- **Cross-Layer**
  - With PHAs, design, help conduct, and assess pilot deployments of end-to-end systems
  - Perform system analysis, modeling to predict effectiveness of end-to-end systems; validate models with real data
  - Provide expert advice, as required and appropriate, to federal, state, municipal, university authorities
- **Help shape impact of this new capability on society**

PHA: Public Health Authority
BLE: Bluetooth Low Energy
UWB: Ultra Wideband
NIST: US National Institute of Standards and Technology

Massachusetts Institute of Technology

Summary

PACT

- 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