The Stadium of the Future

18-738 Sports Technology

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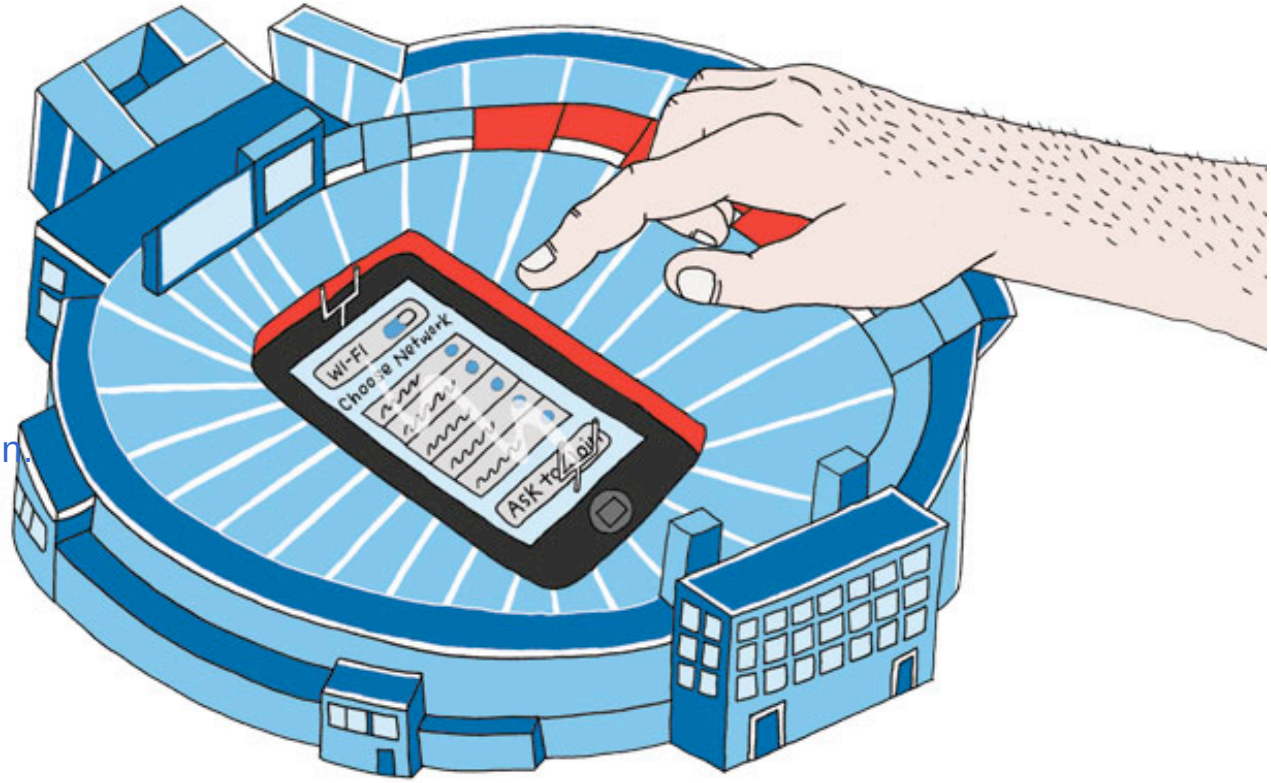
Wireless Technology

- Wireless inside stadiums
  - The need for having connectivity for fans has increased
  - Fairly recent (last 5 years) initiative

Hi-Density Wi-Fi network.
A network that allows a lot of people to share their stuff over the air.

Start to emerge these years,
Aruba, Cisco.

Cisco has a sport entertainment division.



Wireless Technology

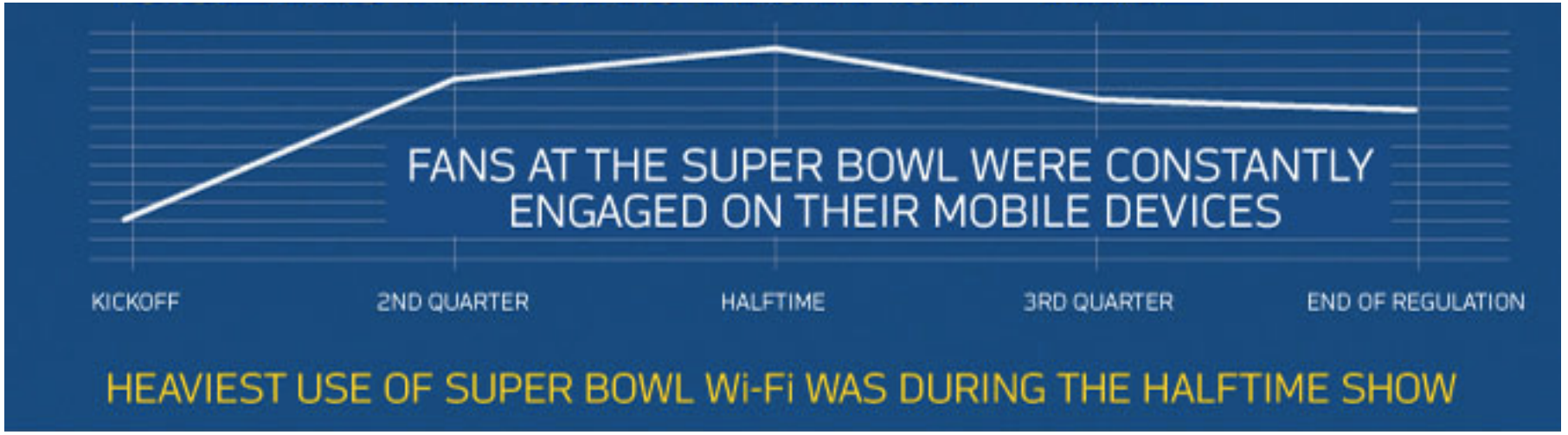
RF is subjective in interferences.

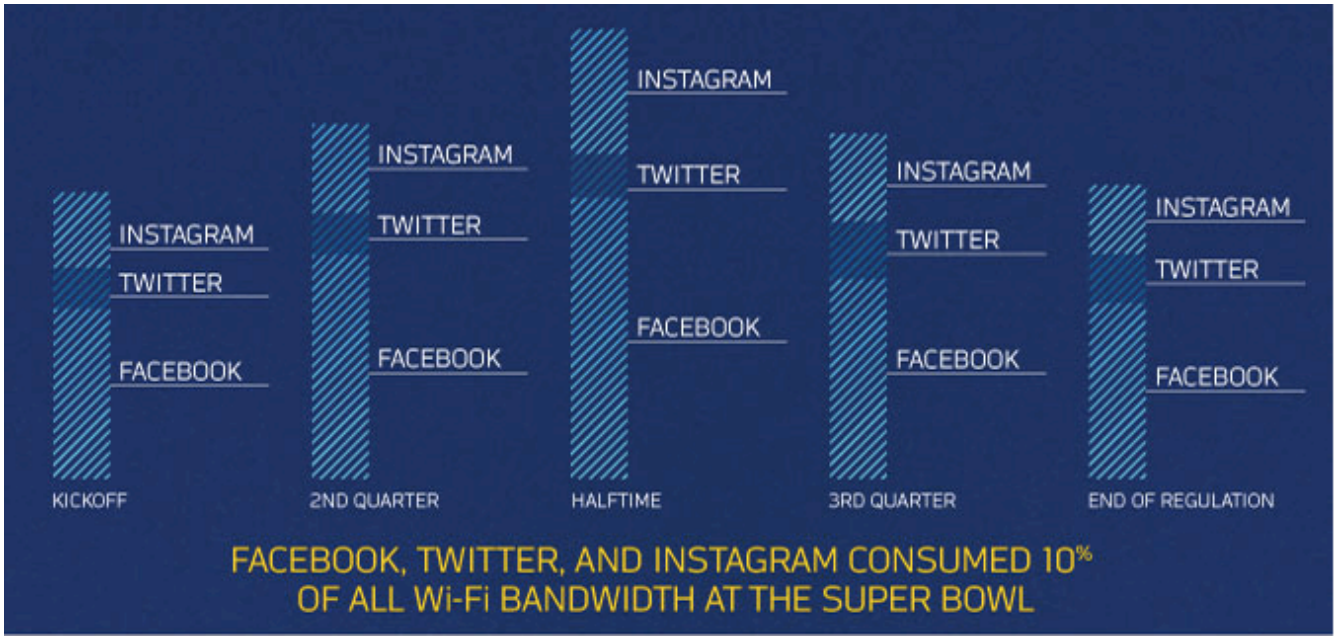
People want to do these in real time.

Demand: real-time, high-density, high-bandwidth.

- Driven by what fans' consumption patterns
- Let's look at Super Bowl XLVIII in New Jersey, 2014
  - Peak usage: 13,500 (of 85,529 fans possible) connected over Wi-Fi
  - 3.2 terabytes of data was transferred over the Wi-Fi system
  - Facebook, Instagram and Twitter responsible for 10% of bandwidth
  - 60% of connected fans shared on Facebook, 18% Twitter, 17% Instagram
  - > 90,000 photos were uploaded to Instagram over Wi-Fi by devices
  - 18% of devices were running software updates
  - Peak usage of Wi-Fi was during the halftime show
- Increased move towards high-density Wi-Fi networks inside stadiums
- Increased discussion of multicast vs. unicast

Wireless Technology





Part of the stadium's infrastructure.

DAS

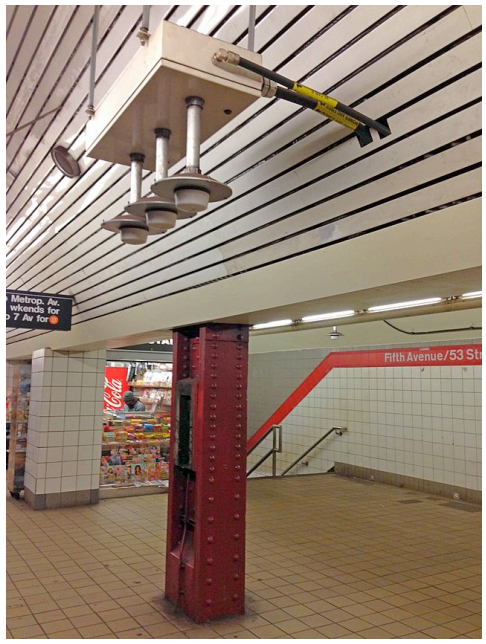
- DAS = Distributed antenna system
  - Network of spatially-distributed antennas connected together
  - Think of a 4G cellular tower broken up into pieces, but distributed indoors
- Replace single antenna radiating at high power with

The entire stadium becomres a base station.

  - Collection of low-power antennas to cover the same area
- What are the advantages?

You concentrate the cecullar power in the stadium

  - Less power wasted in overcoming shadowing losses
  - Line-of-sight channels easier to accomplish
  - Provide higher bandwidth, better coverage
- What are stadiums using?
  - DAS with Wi-Fi offload



Wi-Fi is not off the table. The cecullar system is the bowl. If the DAS does not have enough bandwidth, WIFI will come to offload.

Frequency Coordination in Stadiums

- Most stadiums have an appointed frequency coordinator
  - Challenge to “cram 500 MHz of users into 25 MHz of spectrum”
- Examples of too many people using the same channel/frequency
  - Airline pilots’ conversations (overhead flights)
  - Doppler radar from local weather stations
  - Concession worker requesting additional popcorn supplies
- What is done on game-day?
  - Root out unregistered devices with spectrum analyzer, direction-finders
  - Use time-division and (physical) space-division multiplexing
  - Prioritize the ones that matter (coaching system, under-the-hood review)
  - Provide backups for critical ones (100ft wire for coach-to-coach comms)

Rogue frequency, the frequency that the sport operator should use, but watchers, normal people shouldn't be on. They are not allowed to use.

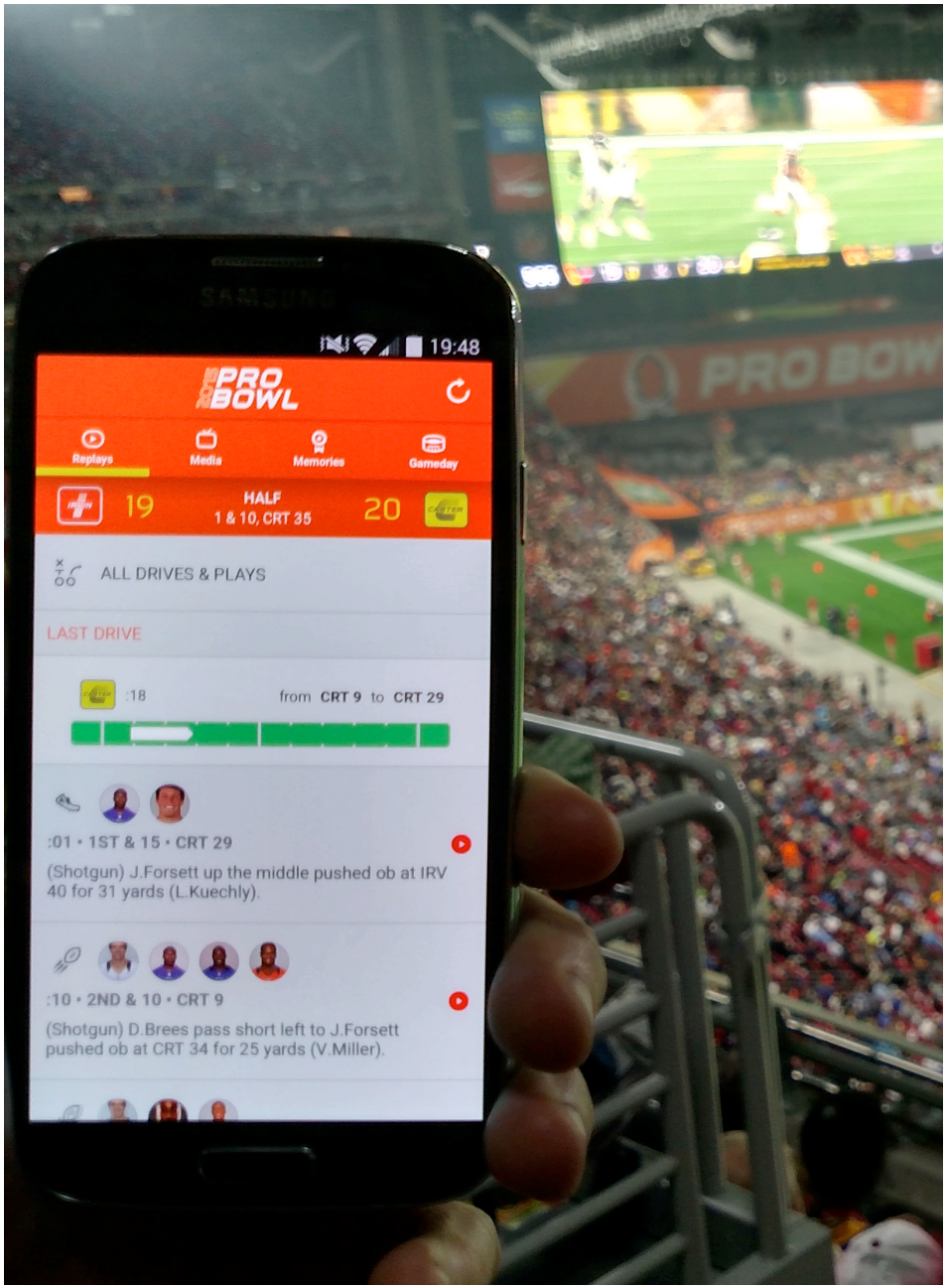
The coordinator walk aroun with a spectrum analyzer, look for rogue frequency.

They hunt down rogue frequencies. There's only finite amount of bandwidth. The coaches communication system that require certain band. If coach cannot communicate with player that's problem.

Instant Replay

- Concept invented by Tony Verna in 1963, to improve the telecast
  - Did not receive a patent/payment for his invention
- Army-Navy game, December 7, 1963
  - Verna had quietly brought with him a giant videotape machine
    Just record the video, and replay on air. This is not live!
  - He had a roll of videotape in the machine ("I Love Lucy," in fact)
  - He was hoping to capture a play and then play it back
  - He captured the touchdown play and it was aired
  - "This is not live! ... Army has not scored again," the announcer shouted
  - By 1990s, instant replay for football, basketball, hockey
  - In 2014, baseball expanded to umpire challenges

Instant Replay (invented 40+ years ago)



What does in-stadium wireless enable?

Courtesy: YinzCam, Inc., Pro Bowl 2015

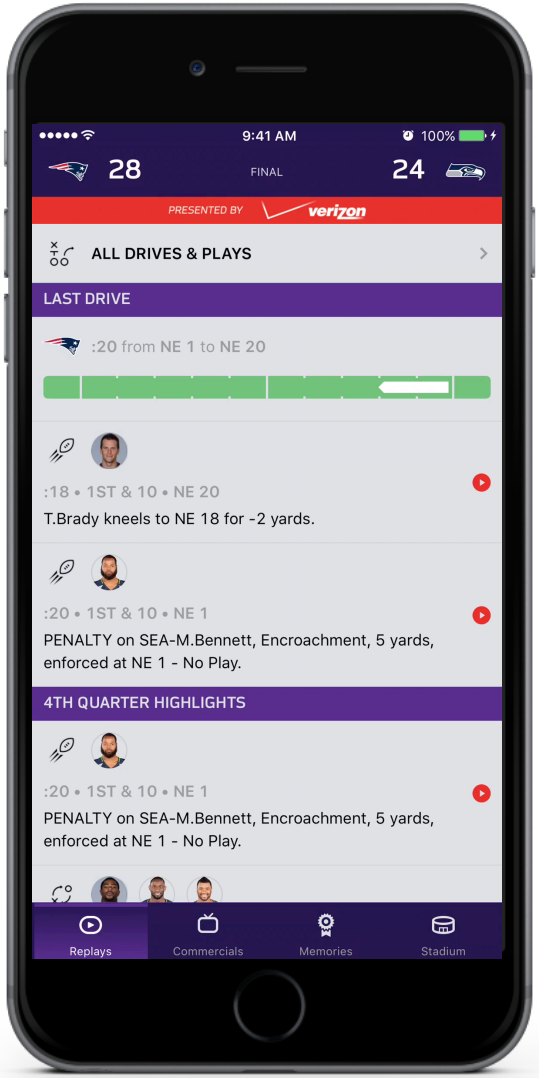
To enable automated replay with machine learning.

Yardage, receiver out of bounds as a fan you want to see the receiver out of bounds for three seconds.

Based on time of play, inbound out of bound, estimate the time to replay

Originally started with NFL, but also works with baskcteball / tennis, now.

Mobile Replays at the Super Bowl



The Advent of Bluetooth LE

- BLE is a wireless personal area network technology

Most of stadiums today has bluetooth low energy.

- Reduced power consumption without sacrificing communication range
- Called Wibree by Nokia in 2006, then named Bluetooth Smart, then BLE
- By 2018, 90% of Bluetooth smartphones expected to support BLE
- Can operate in an advertisement mode to notify nearby devices of presence
- Transmit a UUID
- Bluetooth profiles
  - Healthcare profiles: Blood Pressure Profile, Glucose Profile, ……
  - Fitness: Cycling Power Profile, Running Speed Profile, …..

Bluetooth is not multihop -- it is singlegop. There's limited number of nodes to connect, max 7.
Bluetooth LE beacon is just sending an advertisement packet all the time. I'm this UUID, UUID,etc.

The Advent of Bluetooth LE

- Ideal for applications that require episodic transfer of small amounts of
- Client-server model
- The client wants data (client is typically a smartphone)
- The server has data (server is typically a sensor)
- Bluetooth Smart: Stand-alone BLE sensors (single-mode)
- Bluetooth Smart Ready: Both BLE and Bluetooth Classic (dual-mode)

BLE can run on a single battery for years.

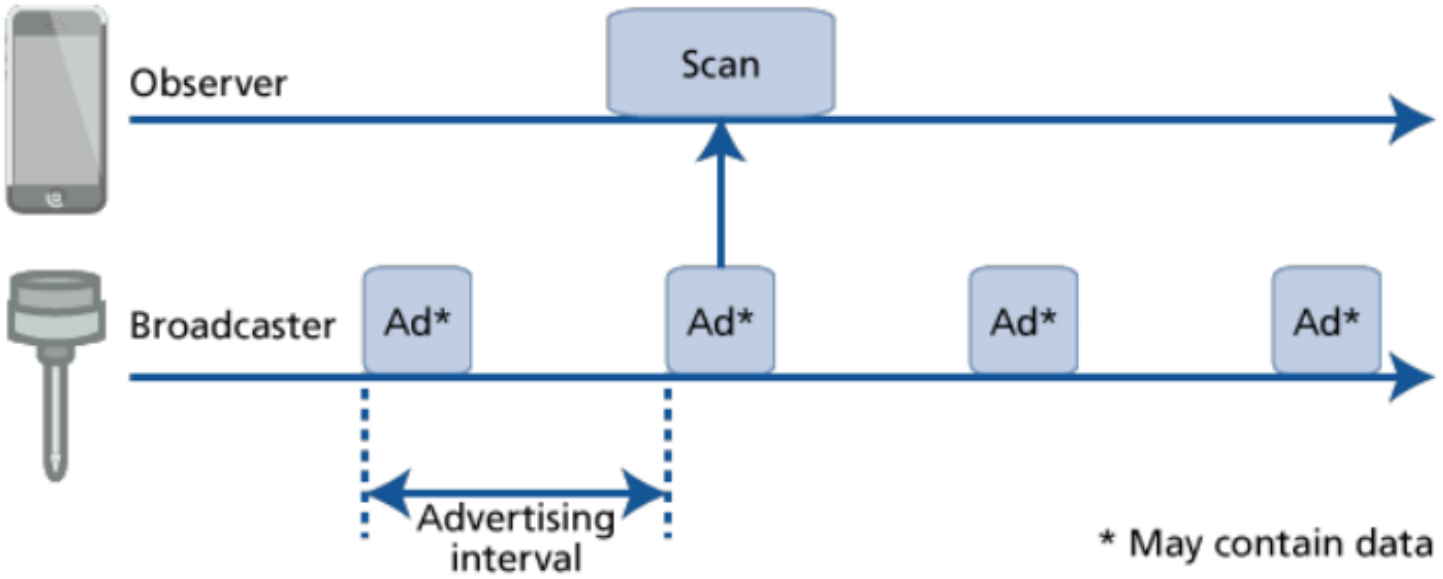
Bluetooth vs. Bluetooth LE

- Just like Bluetooth, BLE operates in the 2.4 GHz ISM band
- Both do Adaptive Frequency Hopping
- Bluetooth hops across 79 channels at 1MHz each
- BLE hops across 40 channels at 2MHz each
- Unlike classic Bluetooth, BLE remains in sleep mode constantly except for when a connection is initiated
- Actual connection times are only a few milliseconds, unlike Bluetooth which would take ~100 milliseconds
- Bluetooth can handle a lot of data, but consumes battery life quickly
- BLE is used for applications that do not need to exchange large amounts of data, and can therefore run on battery power for years

Device Discovery

- Devices are in sleep mode until an advertisement is initiated

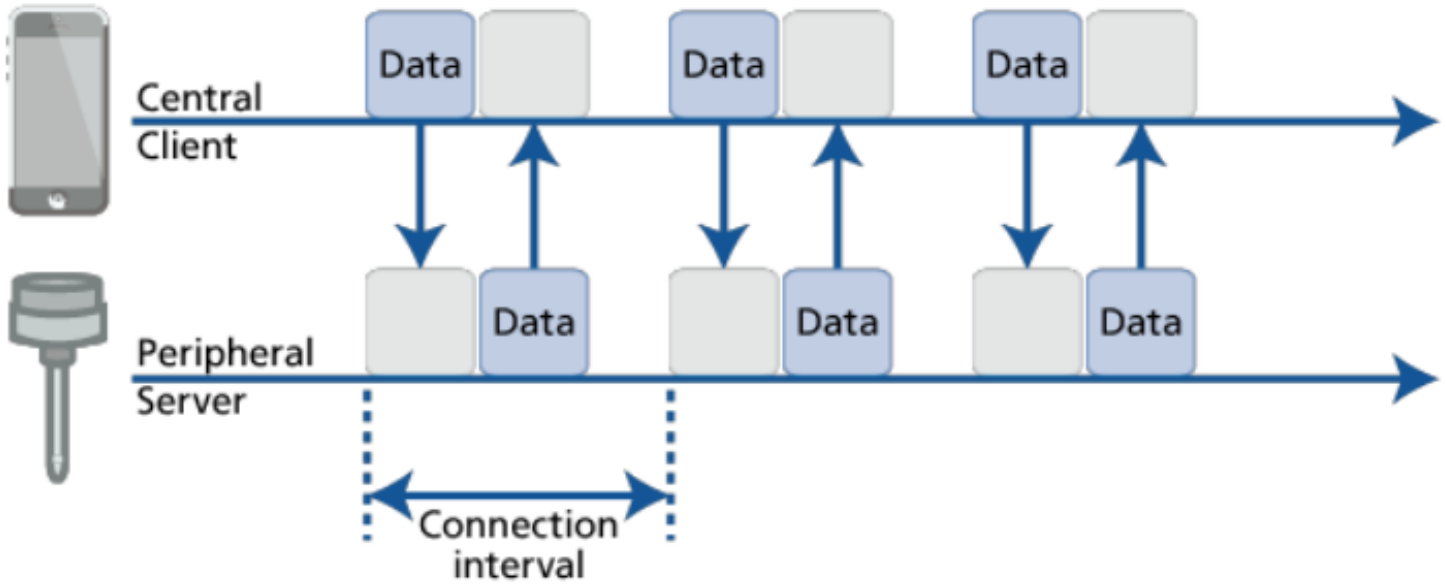
Let the device advertise only once a month.



The devices will be polling each other depending on the applications.

Device Connection

- When connected, then, the devices communicate by polling at intervals
- Application determines the polling interval



What is iBeacon?

BLE is really invented by Apple, now becomes BLE.

- Announced by Apple in 2013, as a part of iOS7

  Apple's standard for BLE.

- Fine-grained location services

- To increase foot traffic to stores

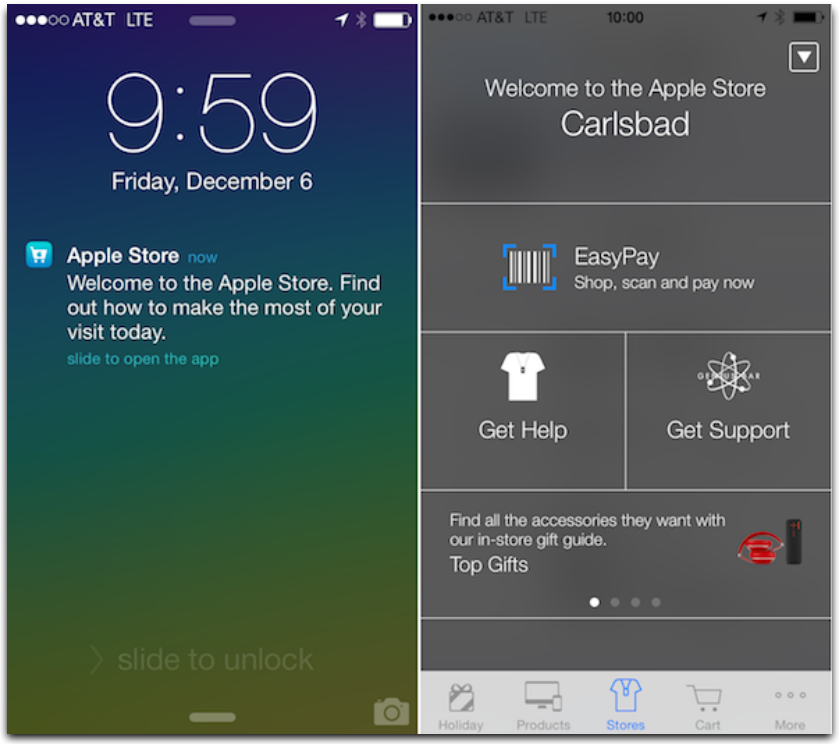
- To reduce showrooming

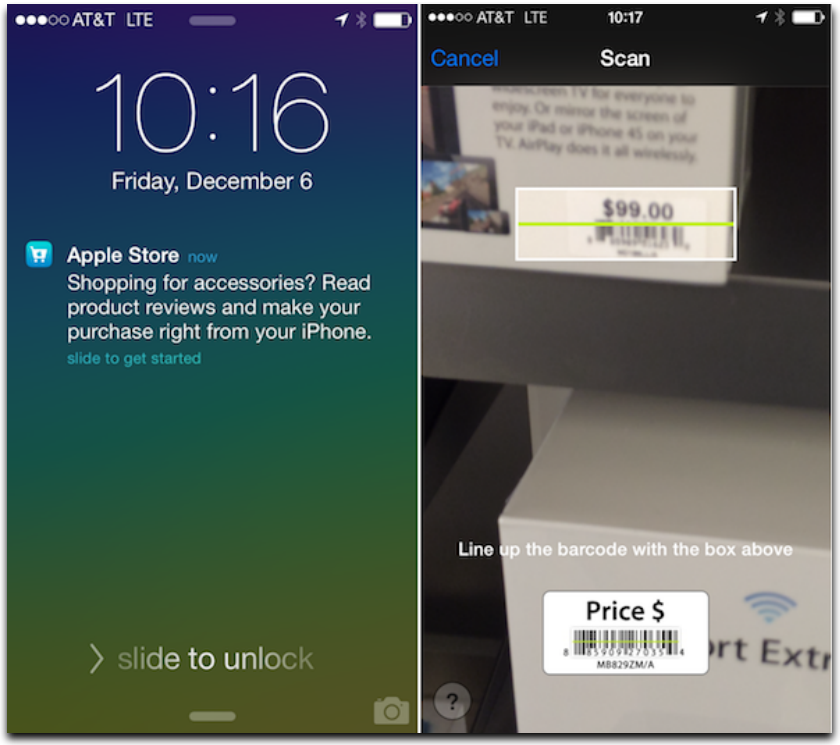
  showrooming, walking there touching many things, but people are not buying anything.

- Installed in 250+ Apple stores

- To create experiences around physical locations, such as ...

The signal strength... 10 dB 75 dB... you can use to detect the distance. Coarse fine level geolocation.





Let’s Go Behind the Scenes

Yet another location service? But why?

GPS gets me to a building, but it does not tell me relative location to landmarks.

- Yes, our phones have maps

- Great for getting to a building, but stops short after that

  GPS has no sense of proximity, it only uses absolute location.

- Accuracy via a combination of cellular, GPS, Wi-Fi

- Accuracy off, much worse in urban areas, in buildings

- No sense of proximity

- No micro-location

Location vs. Proximity

- **Location** is often represented by a point and a radius
- **Proximity** is the fact that you are close to a specific physical location
- “I’m waiting at the bar”
- “I just entered Gate 3 at the stadium”
- “I’m standing in front of a shelf of jeans and jackets”

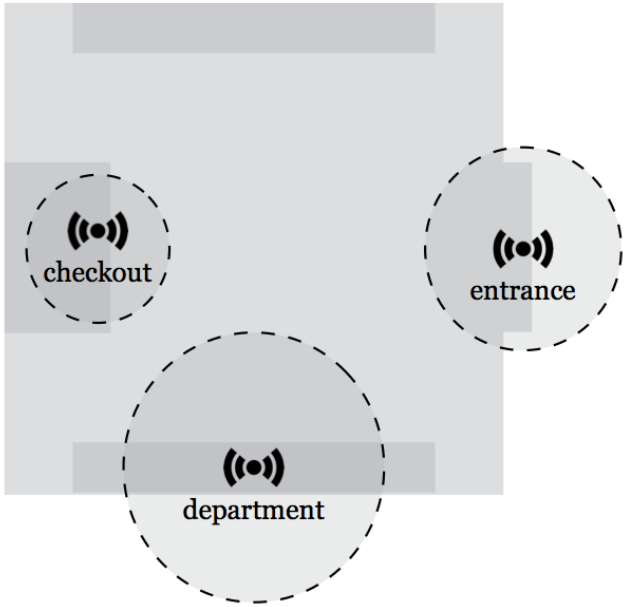
More on Proximity

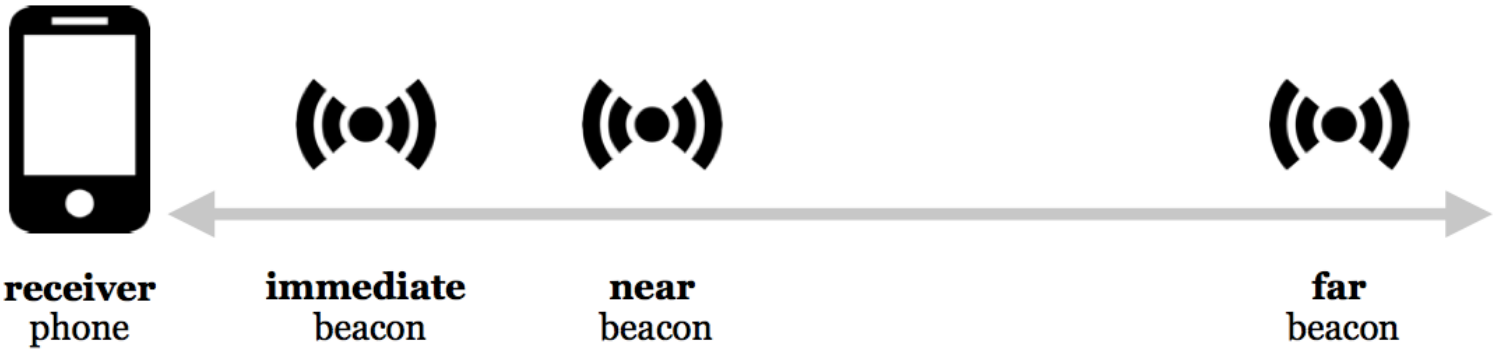
- Transmitter is a beacon, receiver is a phone app

  Notion that I am near or far.

- You can initiate actions based on signal strength

- You can initiate actions “next to,” “nearby,” and “far” from a beacon



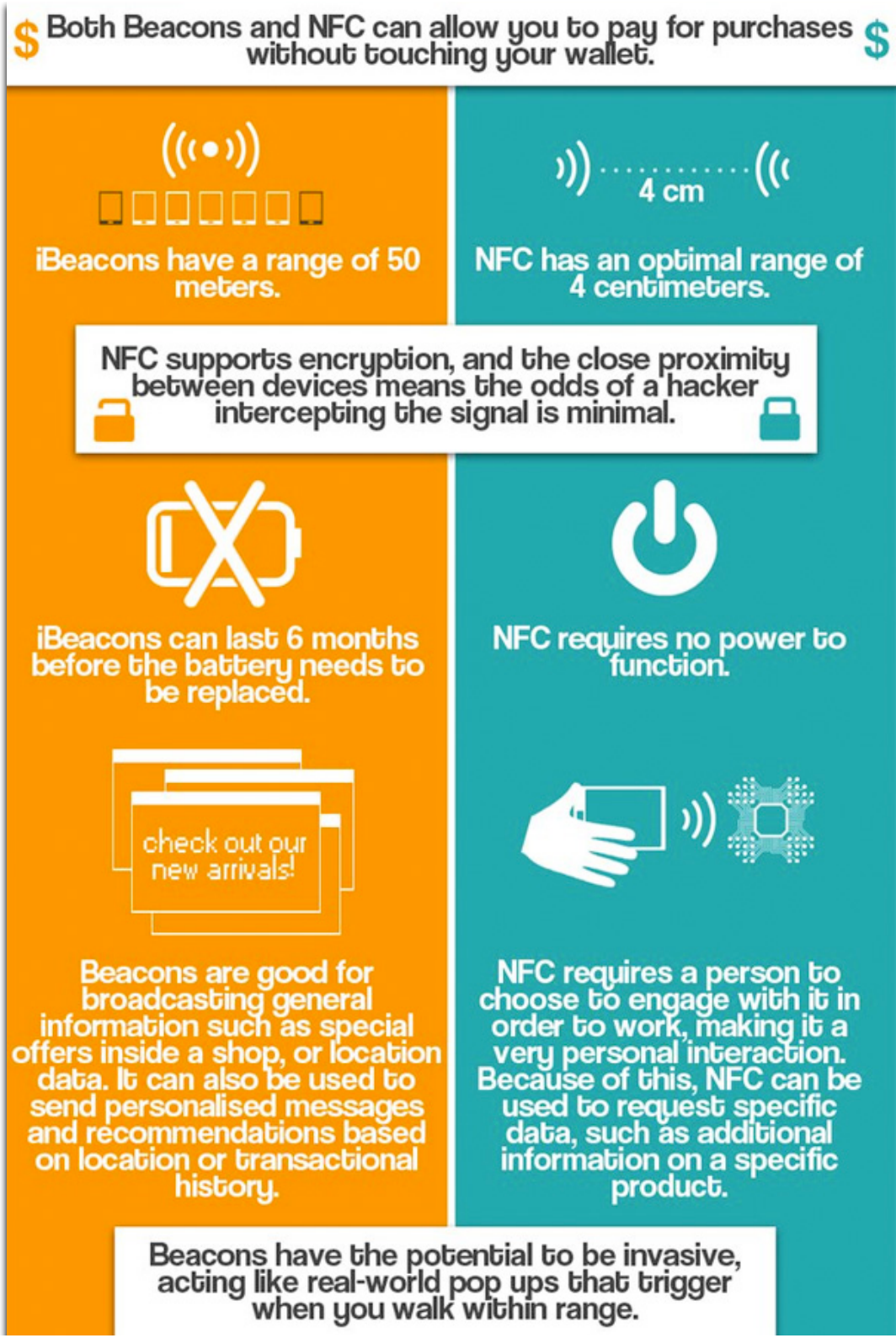


NFC = near frequency card.

NFC is a passive circuit, a printed antenna.

Beacons vs. NFC

- Beacons are small wireless devices that transmit data to smartphones using Bluetooth LE (Low Energy)
- NFC uses short-range radio waves to allow two devices in proximity to exchange data
- Not all phones have NFC
- Most phones have Bluetooth

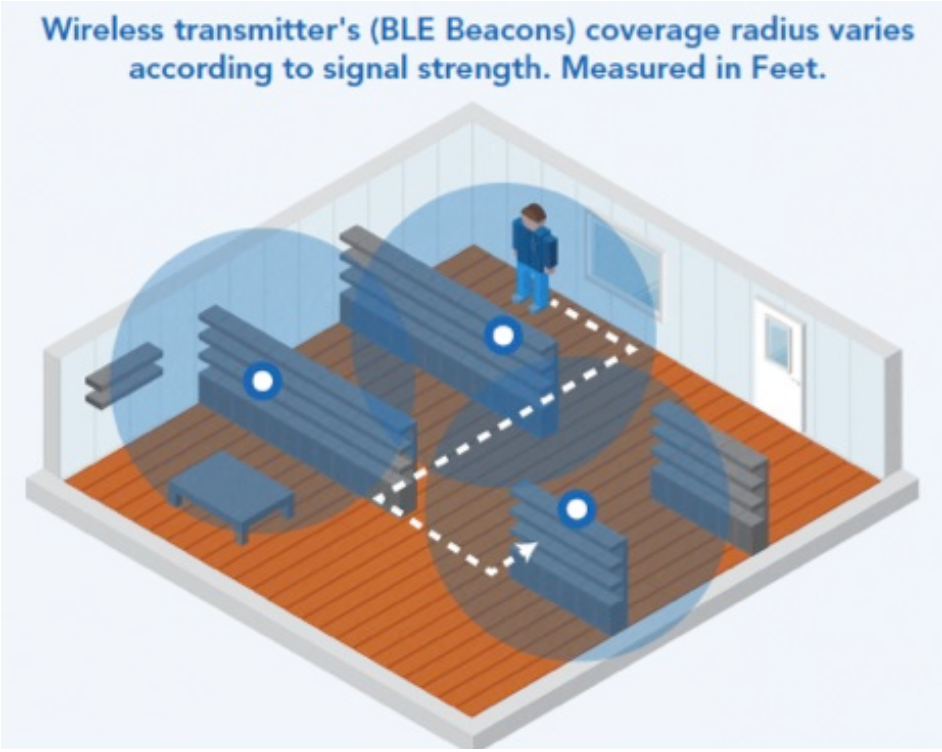


BLE ~= 20 feets away, NFC needs to touch.
NFC = proximity based protocal.

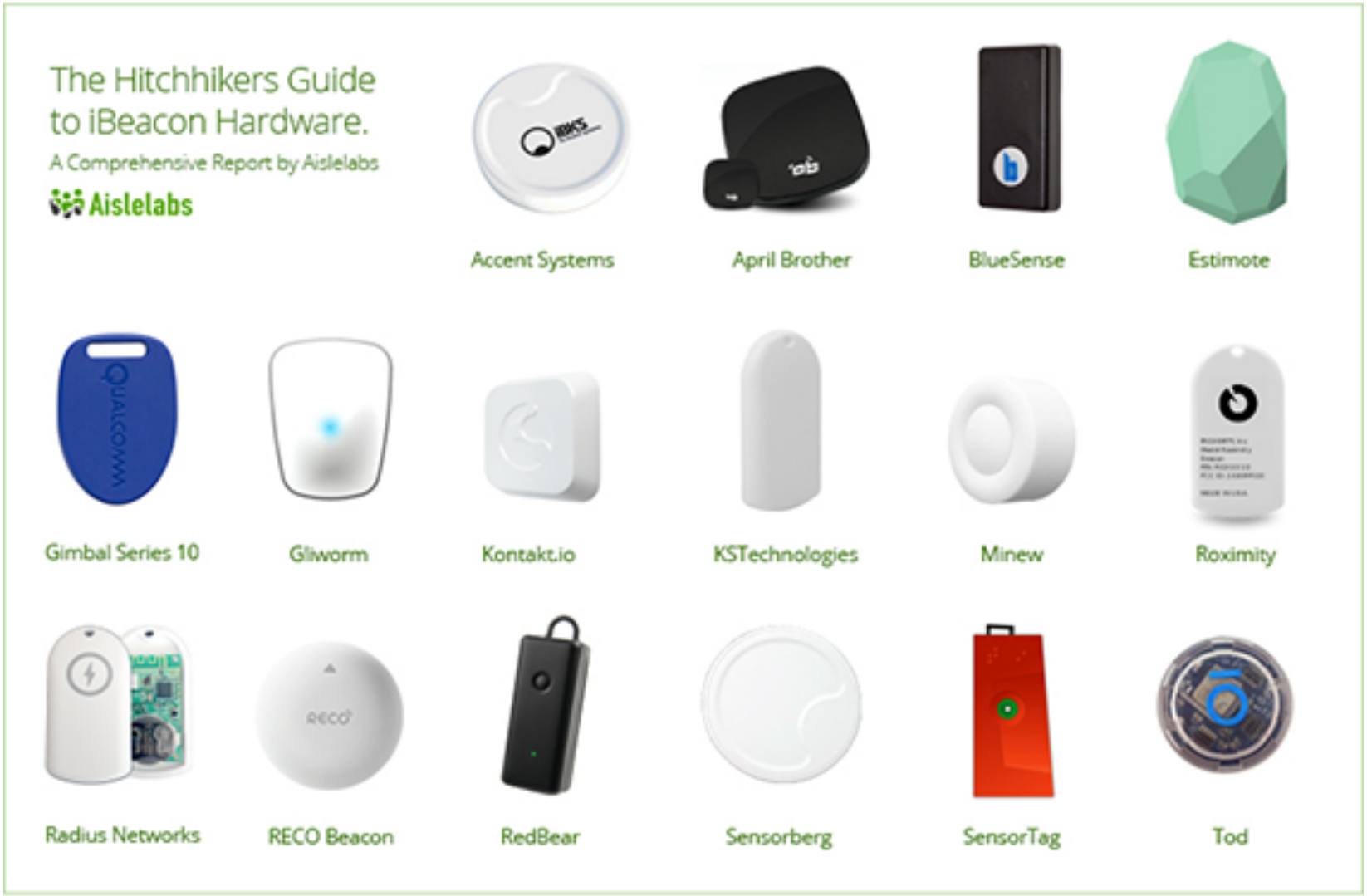
Beacons vs. NFC

- BLE Beacons continually transmit a discovery signal received by BLE-enabled smartphones
- NFC tags only communicate when close to an NFC-enabled smartphone
- BLE beacons' coverage radius can be multiple feet/meters
- NFC tags' coverage radius is centimeters

Proximity-based Micro-location.



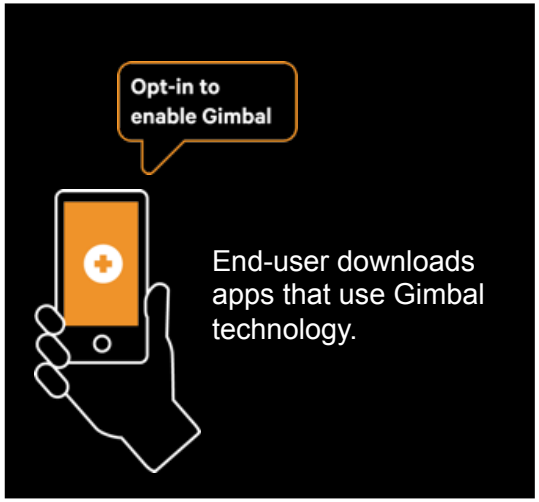
Here a Beacon, There a Beacon

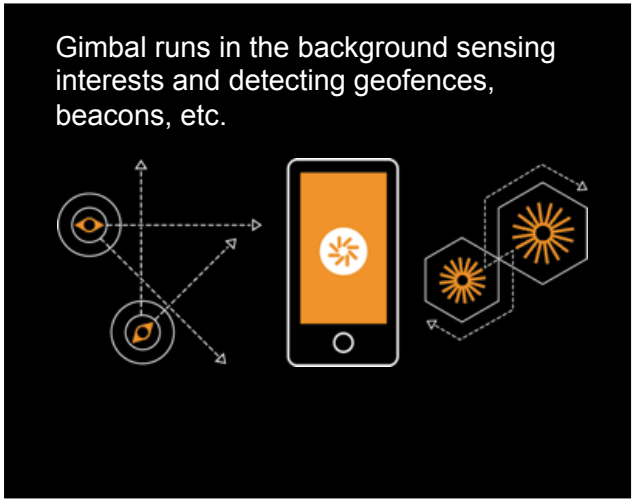


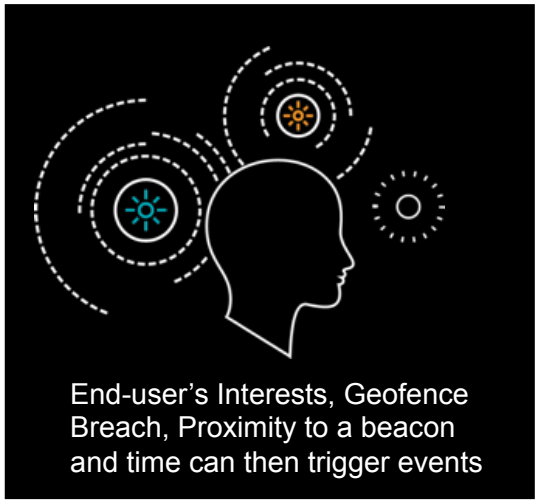
Qualcomm is huge inn BLE.

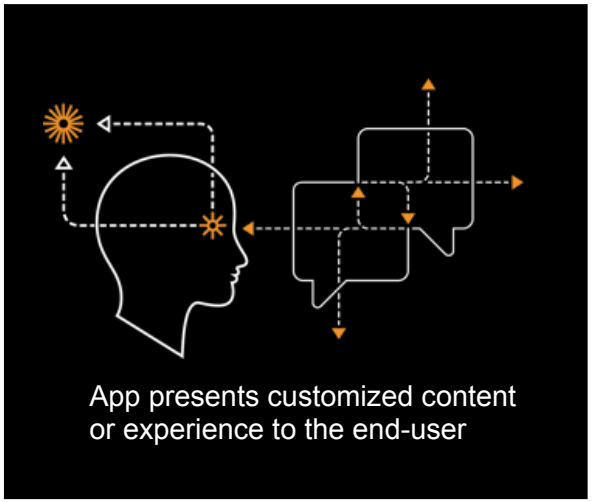
How Beacons Work (from Qualcomm/Gimbal)

Qualcomm gimbal collects data when BLE beacon triggers and trigger events.









What about Privacy?

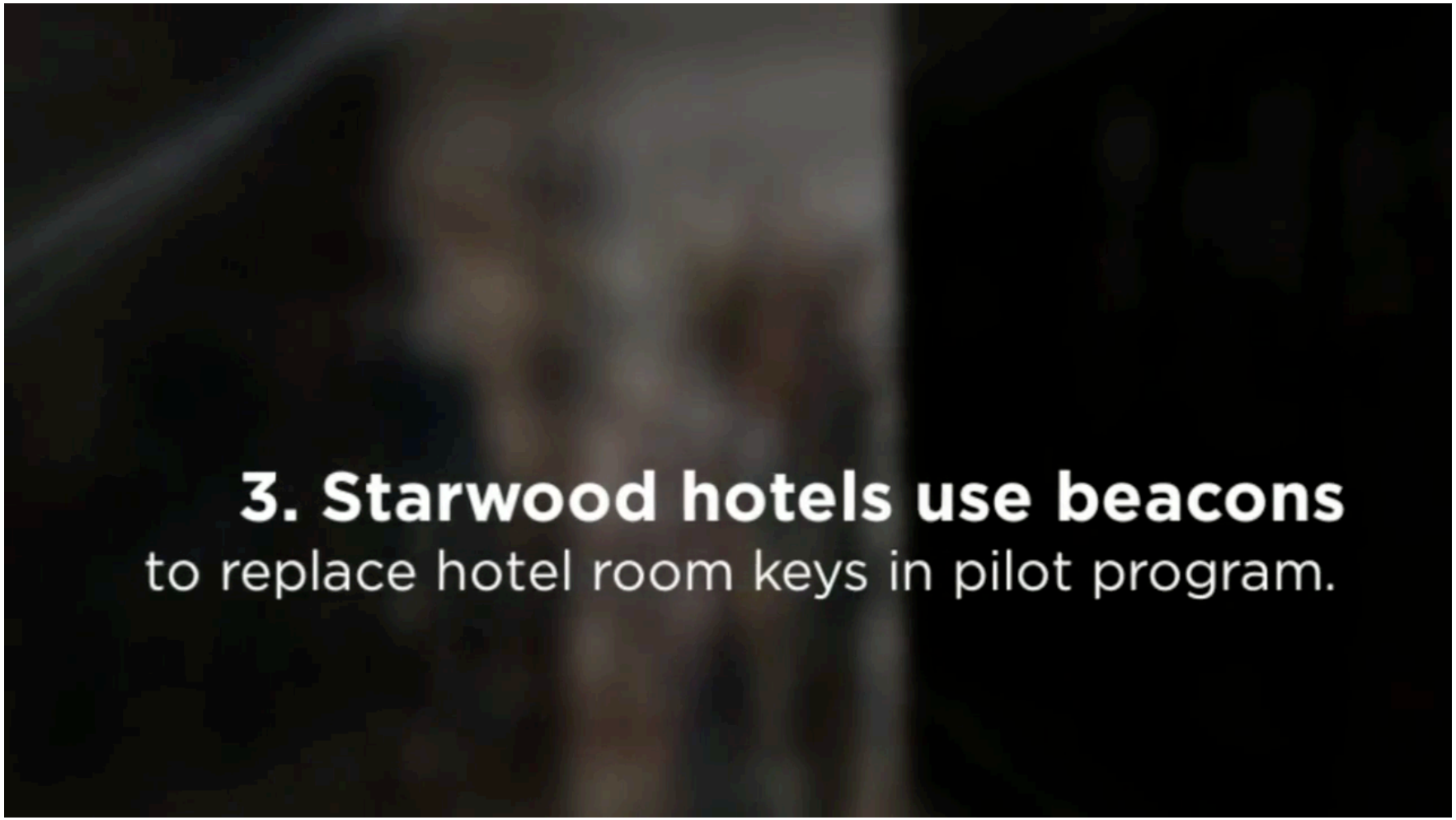
- Opt-in, always
  You choose to join BLE.
- Opt-out with deletion of data
  When you left, deletes datas.
- Dictate which apps have access to which beacons
- Configure/register/unregister beacons
- Configure notifications
- Configure geofences

Several industries are using beacons to change the game

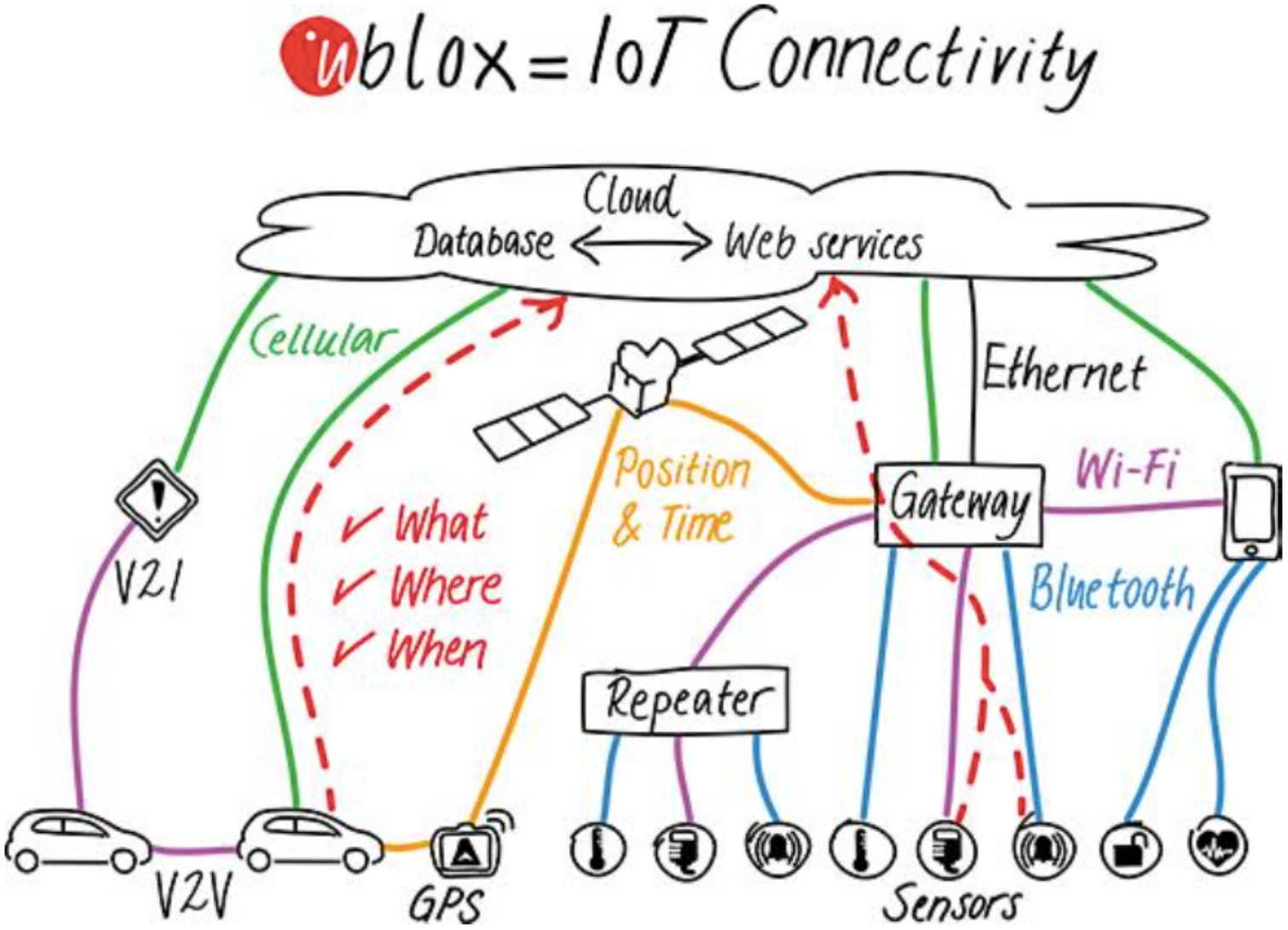
Domains of Interest

Self-guided meseums.

Domains of Interest



How everything works together



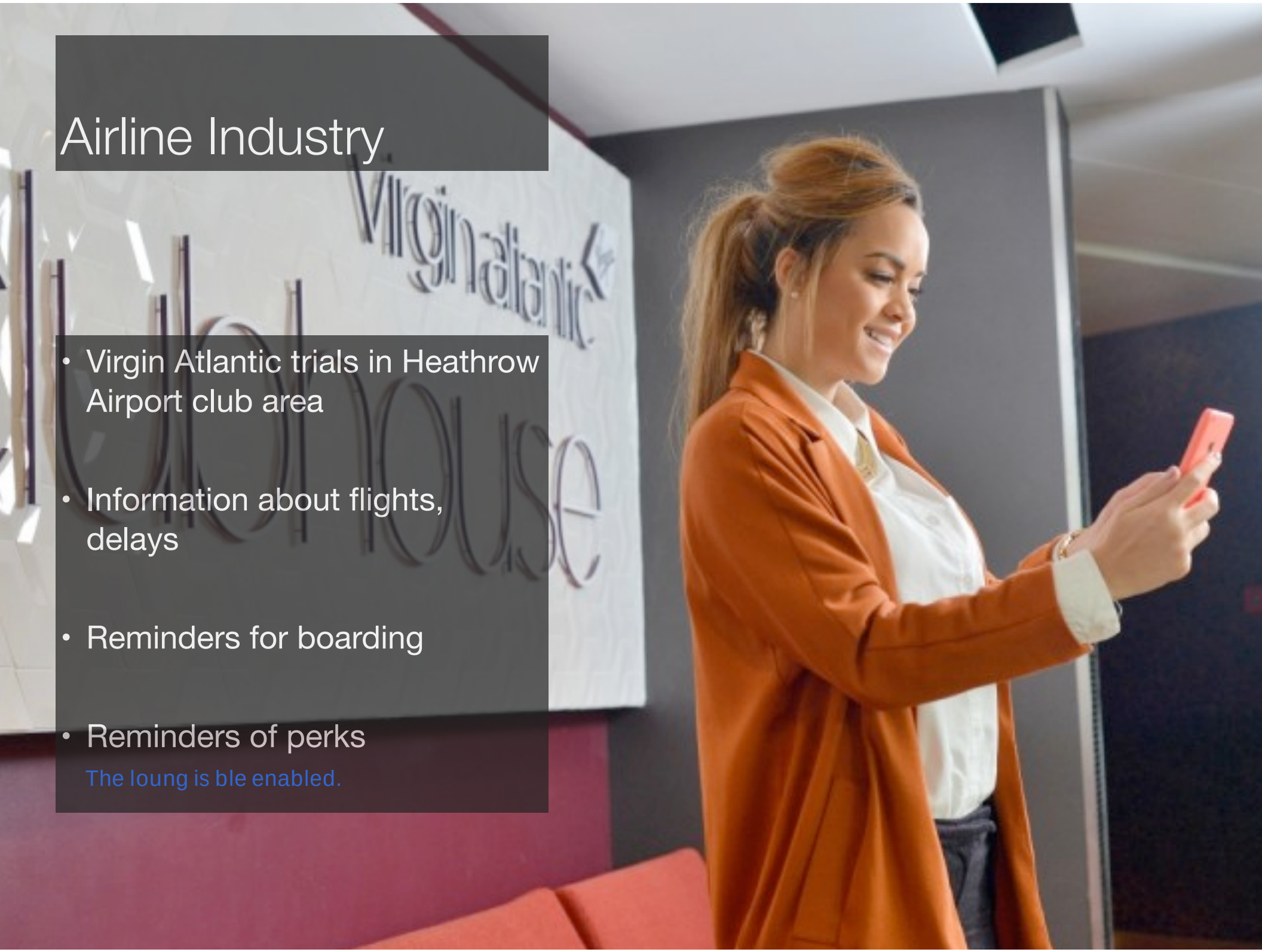
Retail (65%)

Travel & Sports (30%)

Home Automation (5%)

400M beacons out there (as of May 2014)

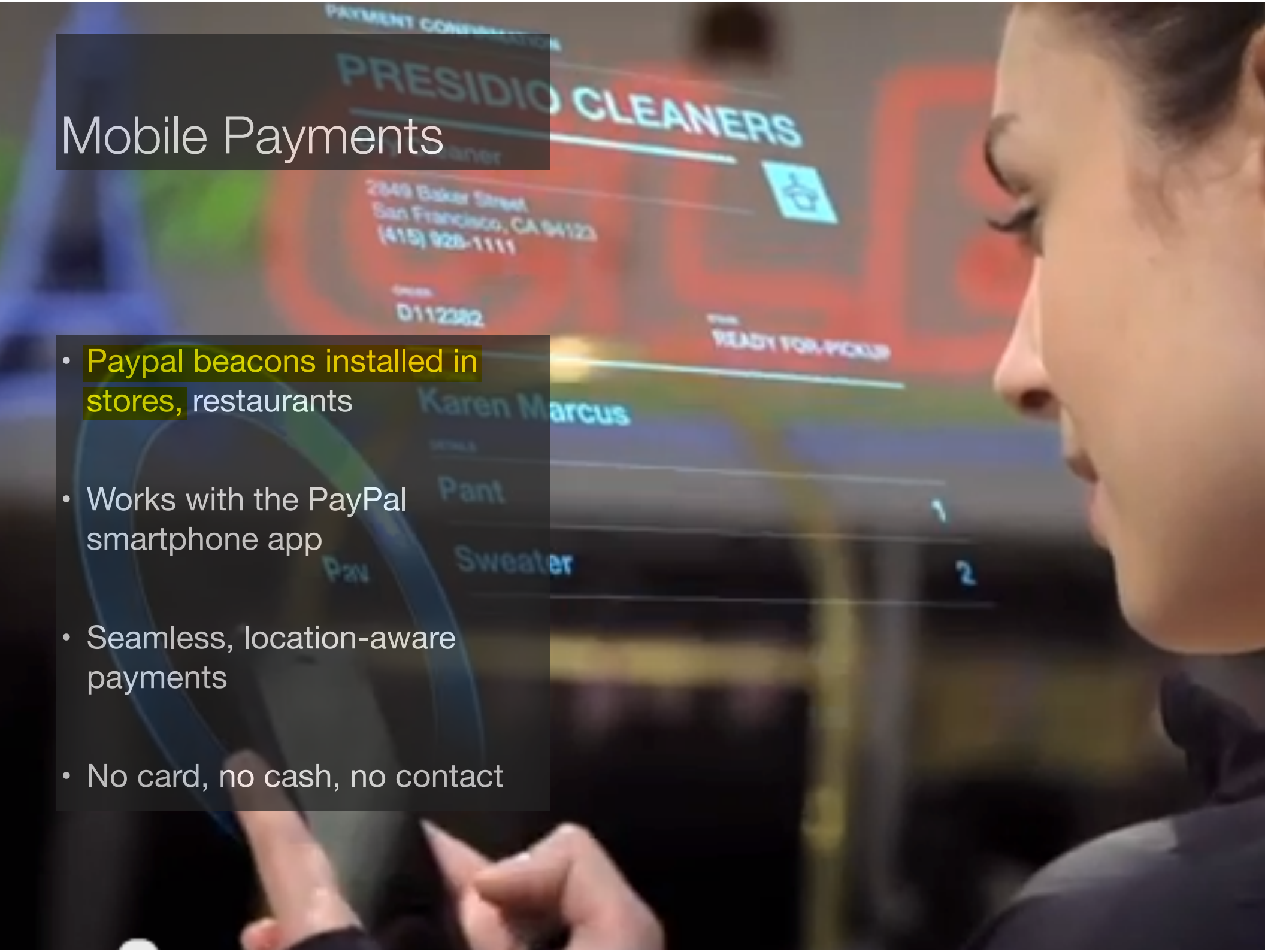
Airline Industry



- Virgin Atlantic trials in Heathrow Airport club area
- Information about flights, delays
- Reminders for boarding
- Reminders of perks

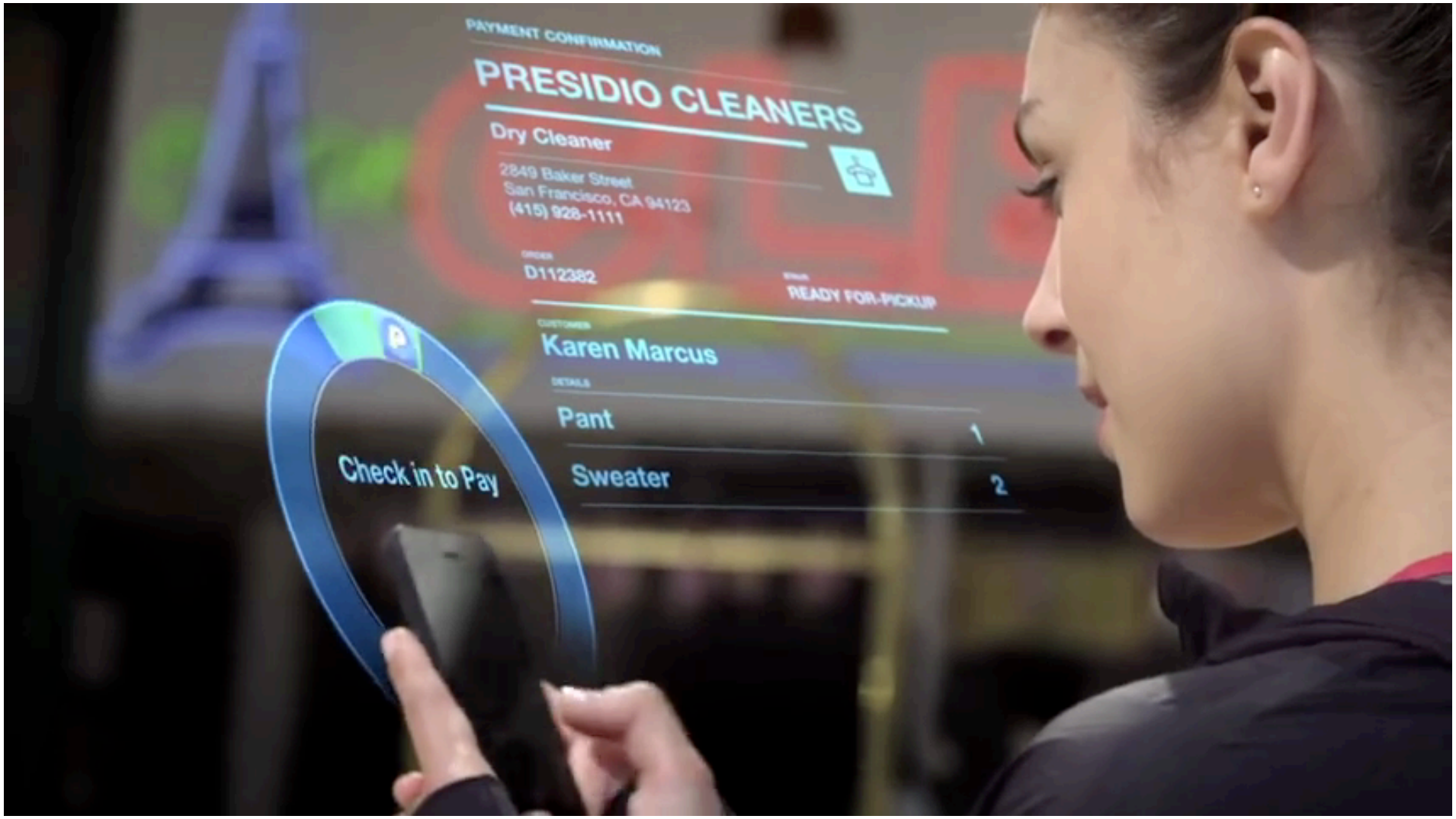
The loung is ble enabled.

Mobile Payments

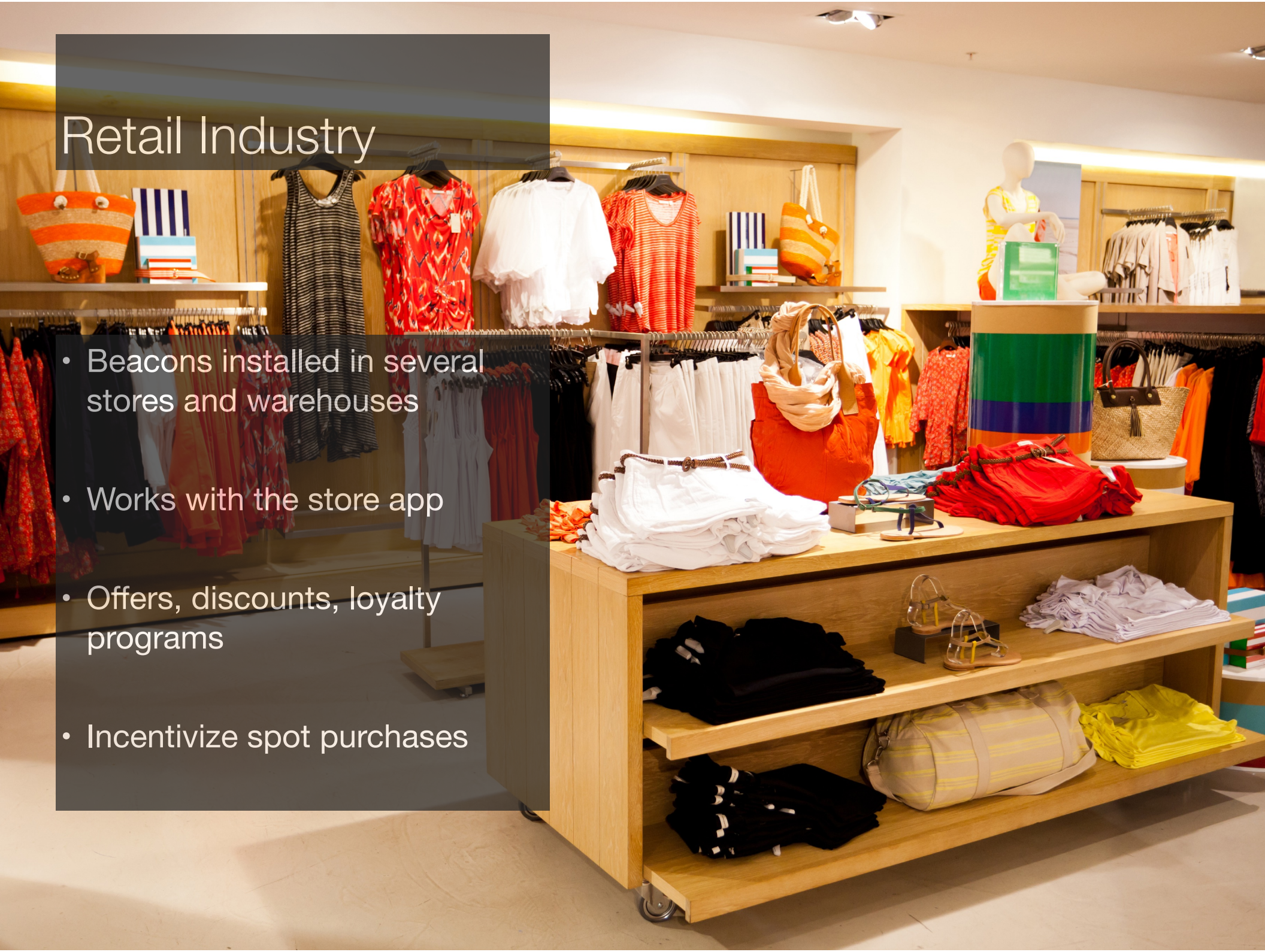


- Paypal beacons installed in stores, restaurants
- Works with the PayPal smartphone app
- Seamless, location-aware payments
- No card, no cash, no contact

Mobile Payment with Beacons are happening in the stadiums everyday.

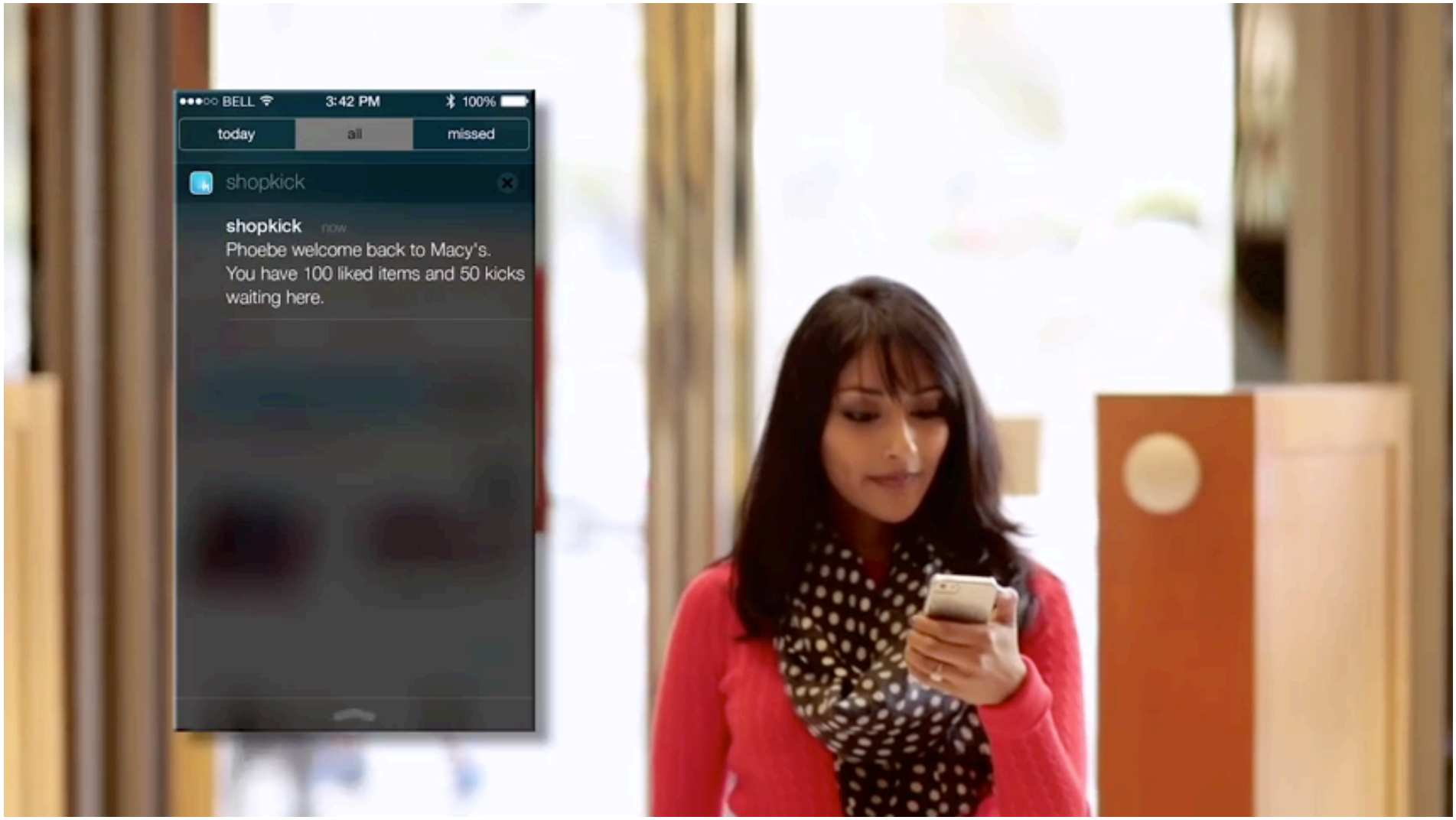


Mobile Payments



Retail Industry

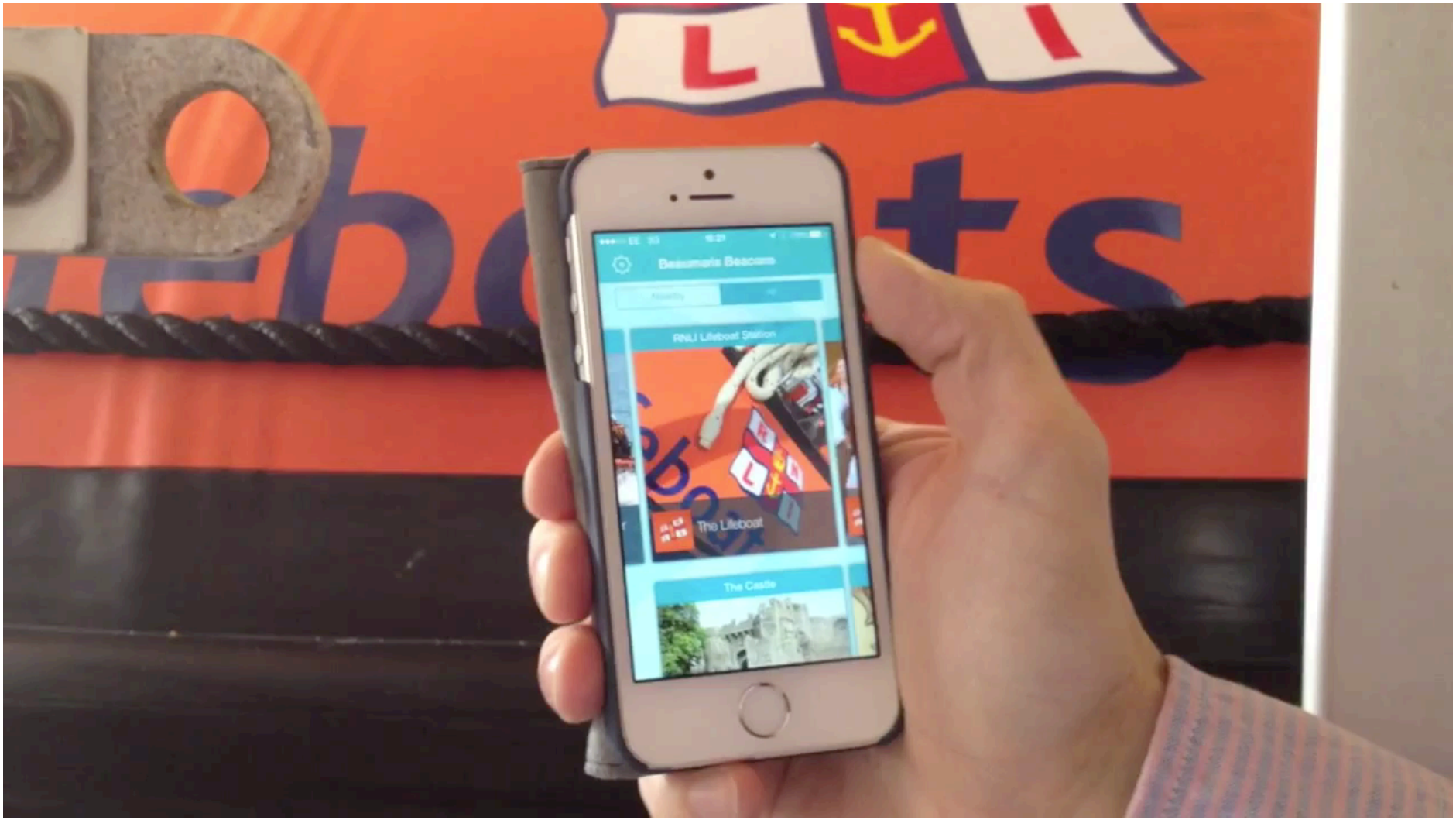
- Beacons installed in several stores and warehouses
- Works with the store app
- Offers, discounts, loyalty programs
- Incentivize spot purchases



In-Store Experiences

Smart Cities

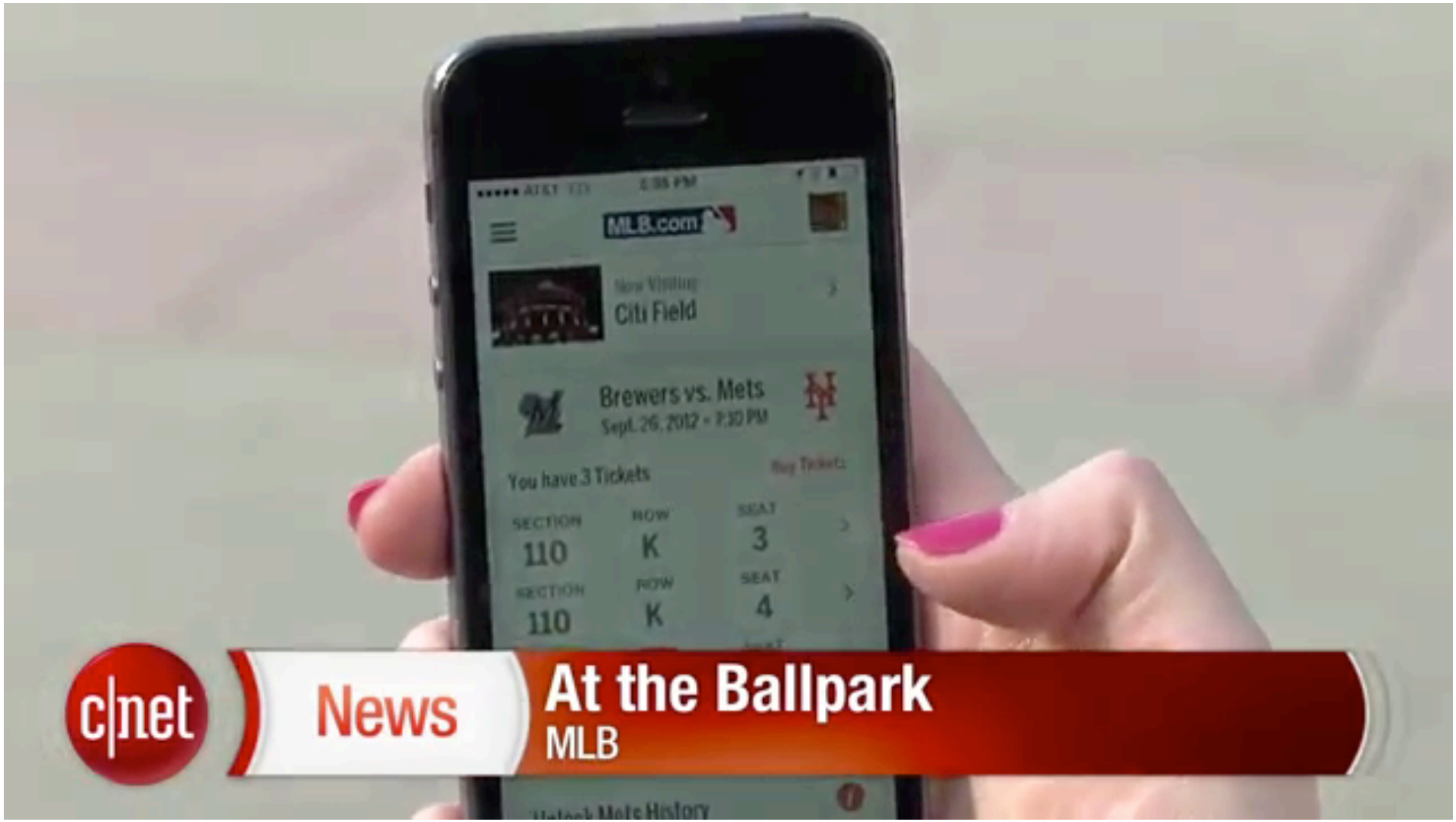
- Beacons installed in cities, e.g., New York City
- Works with the city app, retailers' apps, transportation apps
- Information about attractions
- Transportation information



In-Store Experiences

Sports Industry

- Beacons installed in several stadiums and venues
- Works with the venue/team/ league app
- Experiences associated with physical artifacts (hall of fame)
- Loyalty programs, season-ticket holder experiences



Interactive In-Stadium Experiences

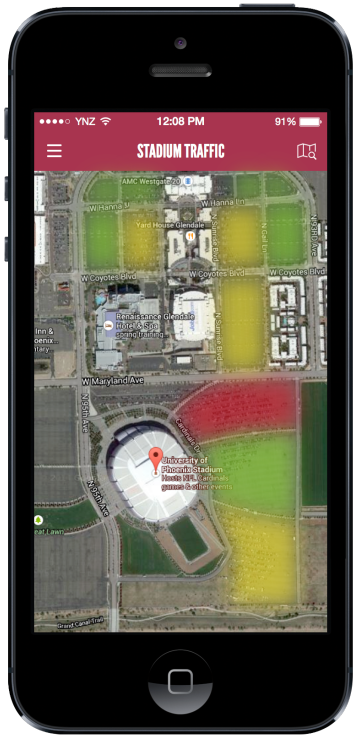
Out-of-stadium ingress, egress & parking congestion

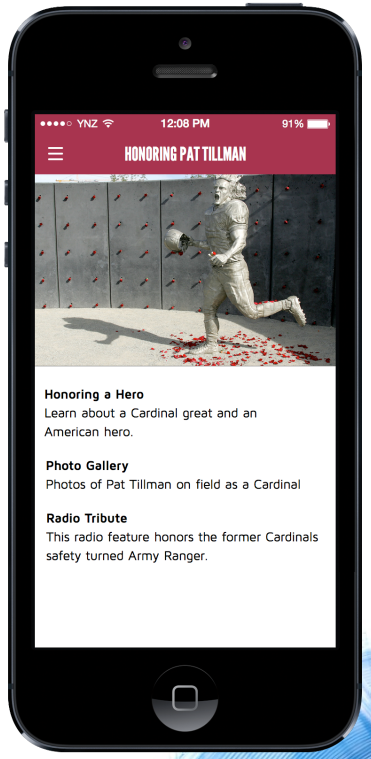
Interactive exhibits

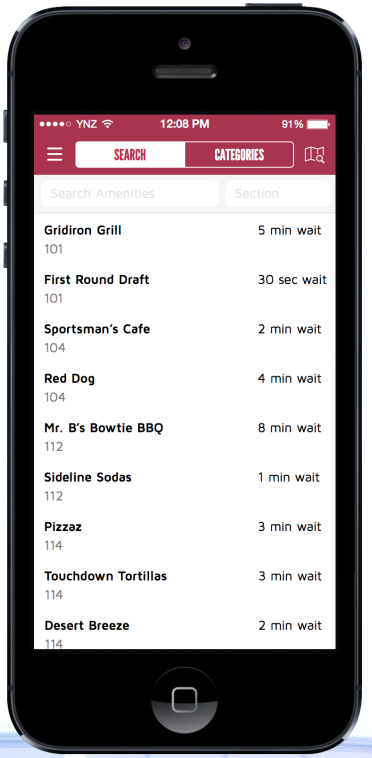
In-stadium congestion

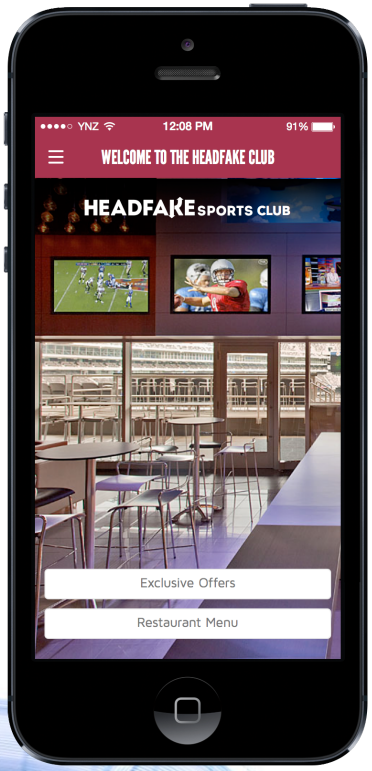
Wait-times

VIP areas









Beacon-Activated Fan Journey

Check-ins

- Enable fans to checkin on gameday

- “Construction on Route 39”
- “Tailgating starts at lot 4”
- “Don’t miss halftime show”
- “Kickoff in 5, head to your seats”
- “Welcome to the Ford Sideline Club”

- Selfies made easy

Offers

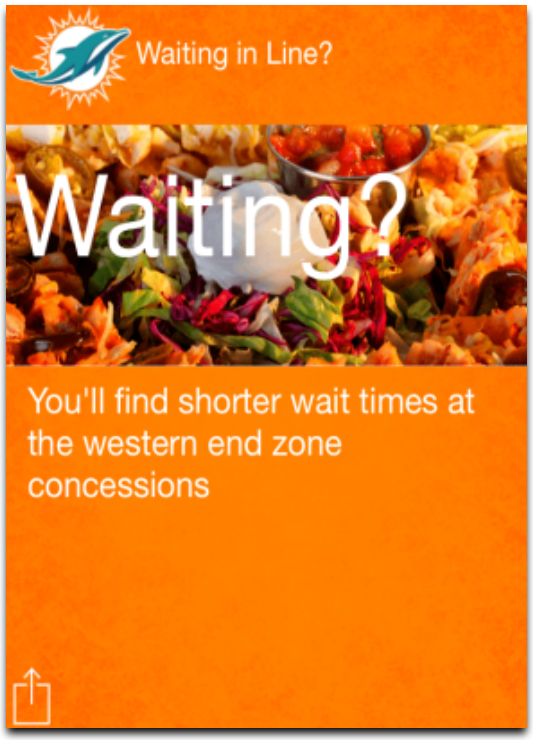
Micro-location - I got UUID for the beacon, you don't have longtitude and latitude, you know proximity of a person.

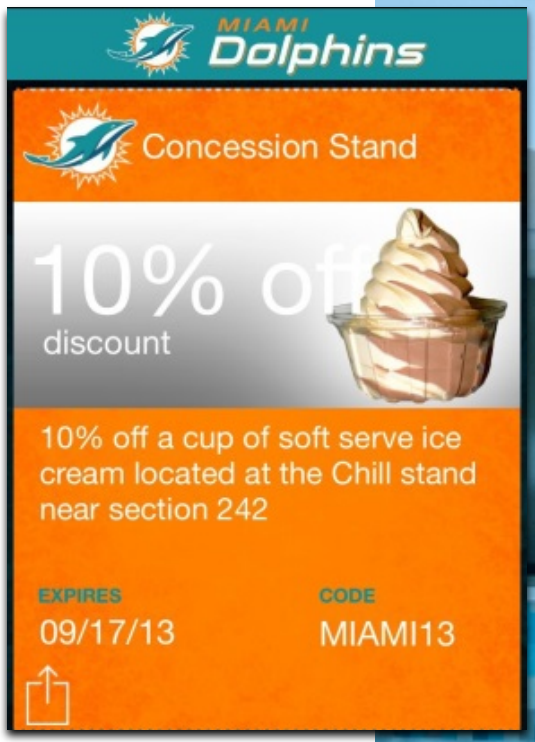
- Enable fans to know of merchandise

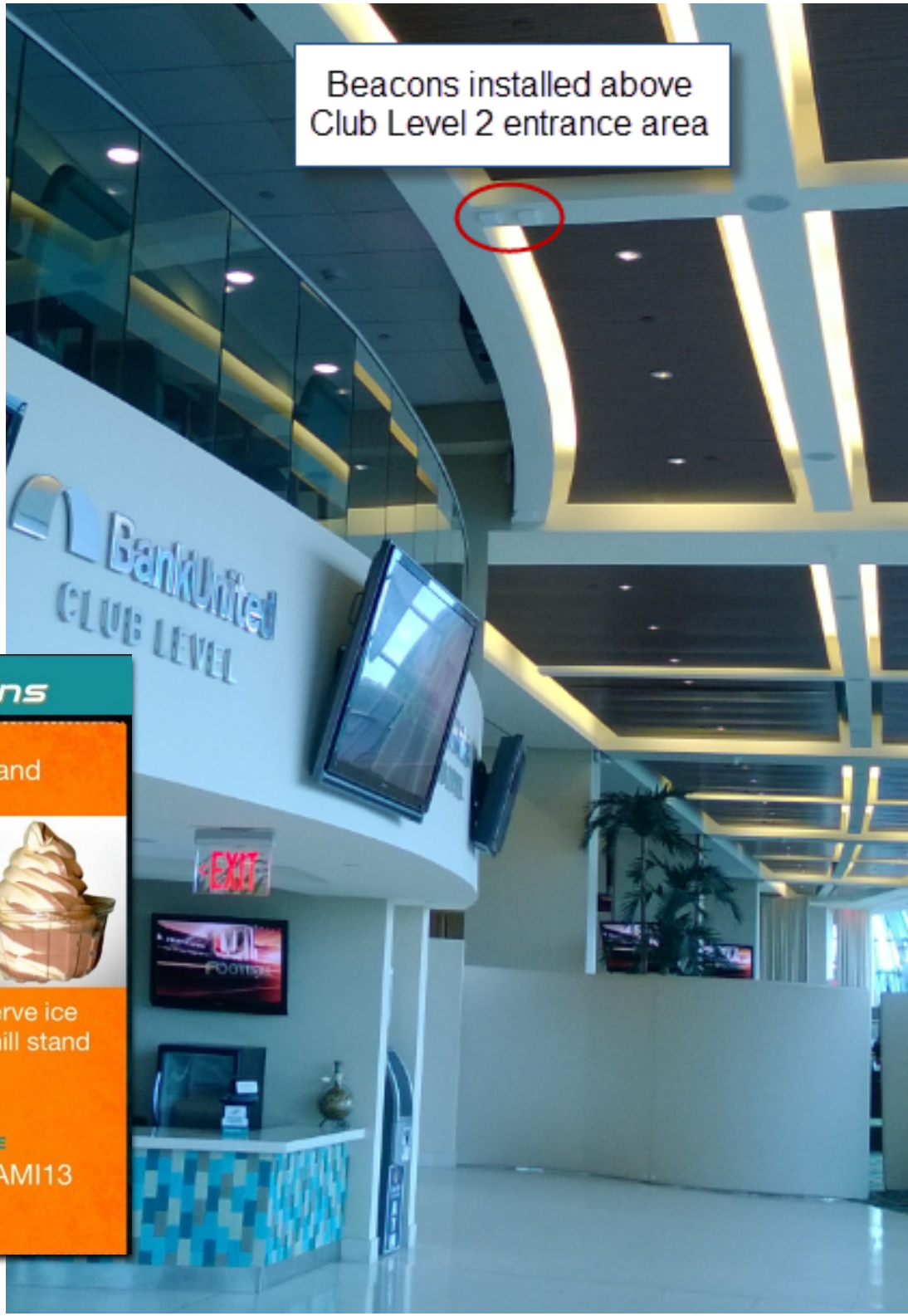
- “10% off team jersey”
- “Top selling jersey is #54”
- “Stop by for your free bobblehead”
- “Employee discount of 30% today”

Line-Busting

- Enable fans to know of wait-times
- Discounted offers for concessions
- Knowledge of new concession items



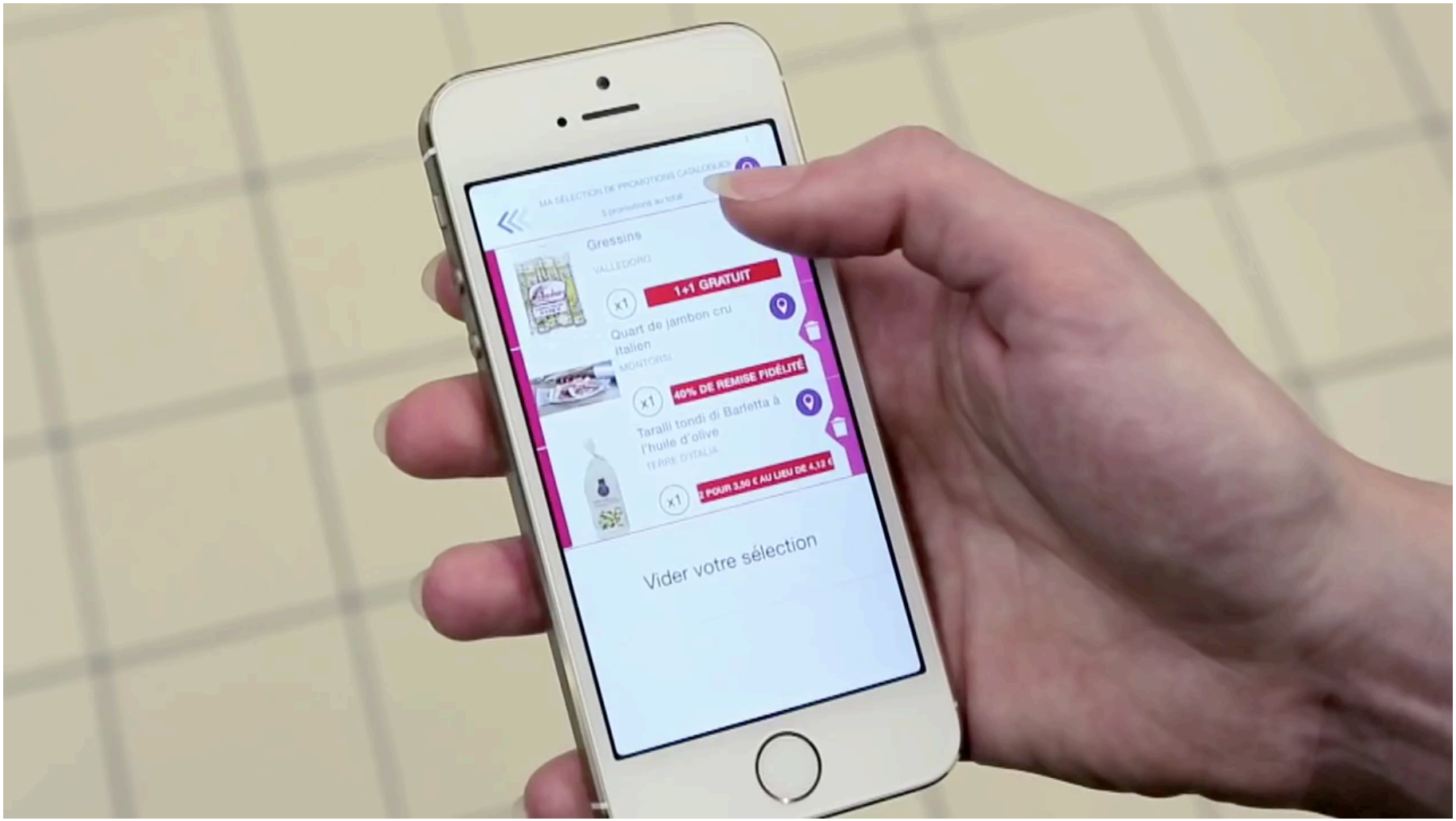




Experiences/Content

Competing Technologies (Visible Light)

Competing Technologies (Visible Light)



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