

# Internet of Things

Everything will be connected

The Stadium of the Future  
18-738 Sports Technology

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# Wireless Technology

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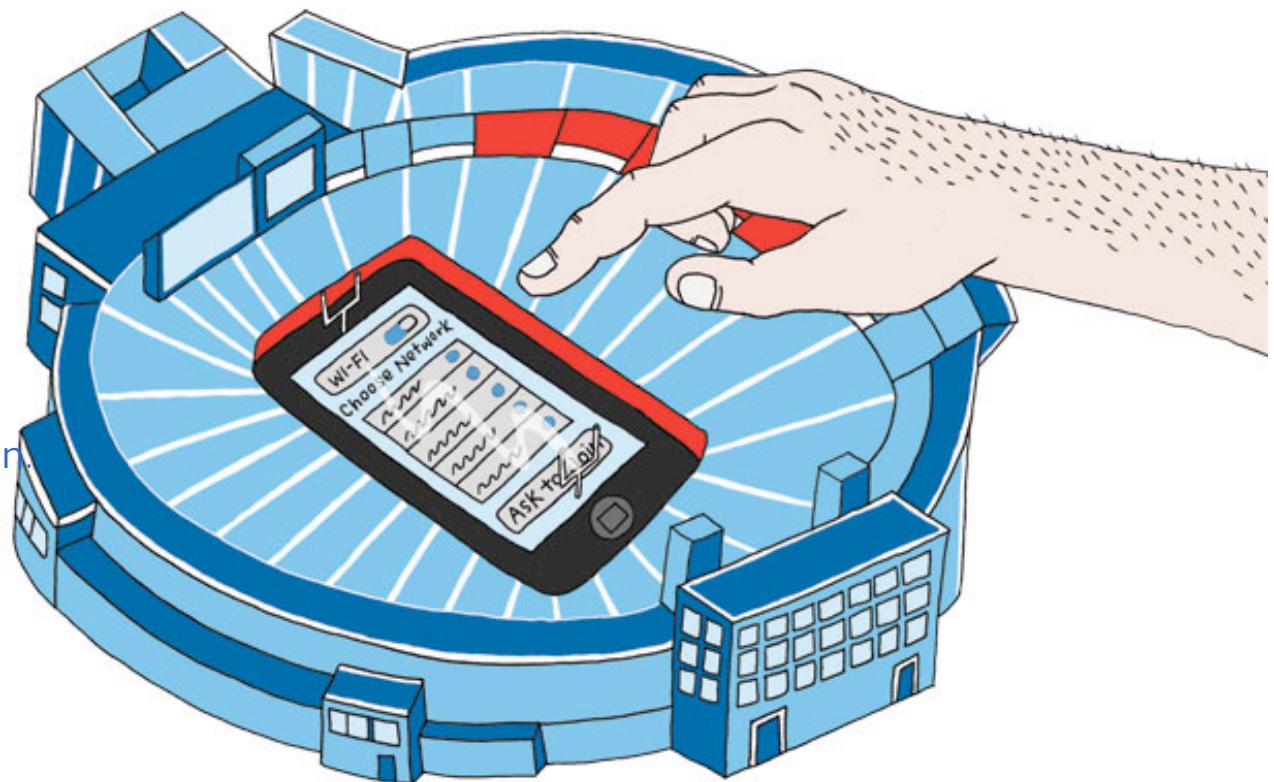
- Wireless inside stadiums
  - The need for having connectivity for fans has increased
  - Fairly recent (last 5 years) initiative

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.

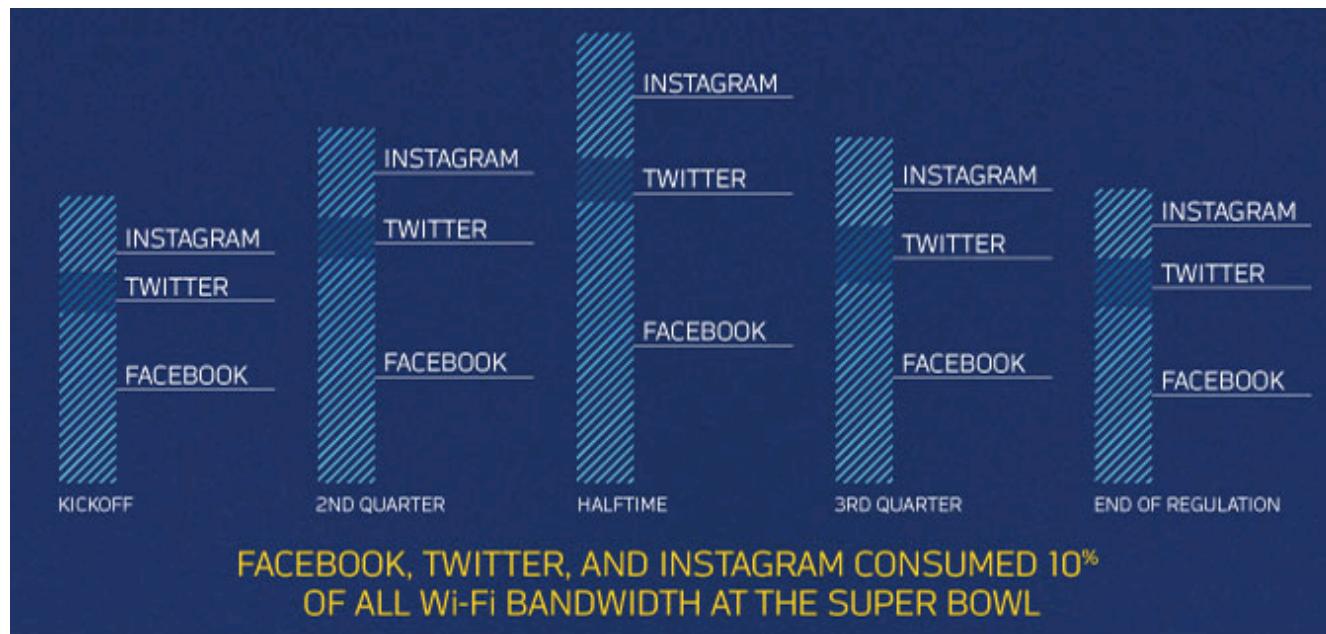
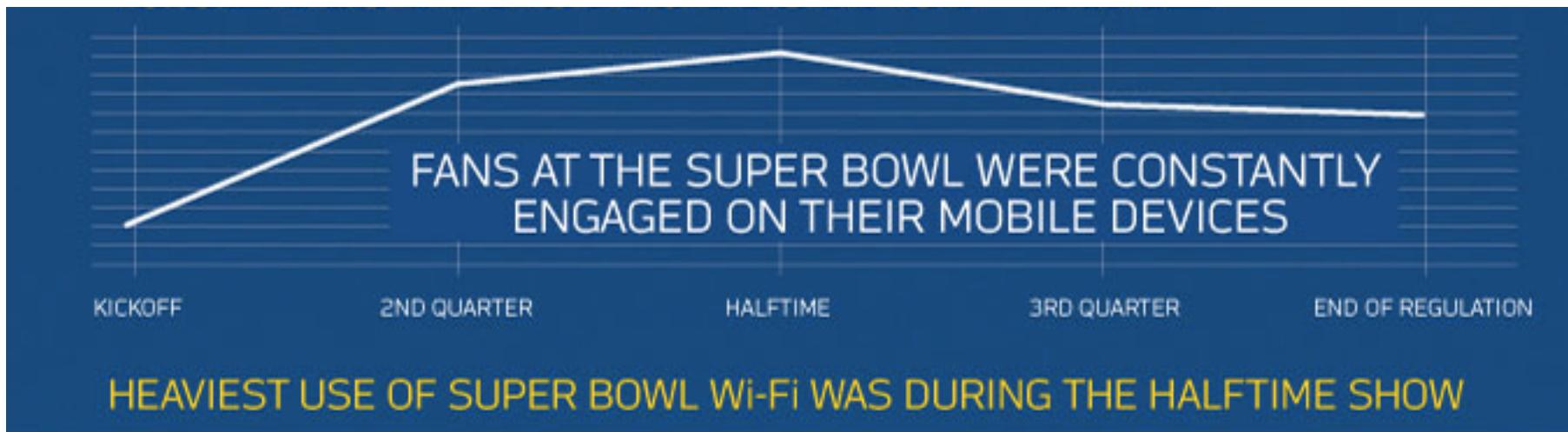
People want to do these in real time.

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

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- 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

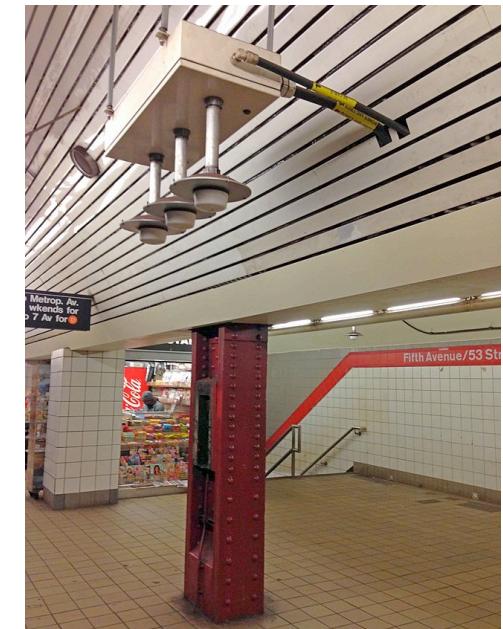


Part of the stadium's infrastructure.

# DAS

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- 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 becomes a base station.*
  - Collection of low-power antennas to cover the same area
- What are the advantages?  
*You concentrate the cellular 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 cellular system is the bowl. If the DAS does not have enough bandwidth, WiFi will come to offload.*



# Frequency Coordination in Stadiums

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

- Most stadiums have an appointed frequency coordinator
  - Challenge to “cram 500 MHz of users into 25 MHz of spectrum”  
The coordinator walk around with a spectrum analyzer, look for rogue frequency.
- 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  
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.
- 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)

# Instant Replay

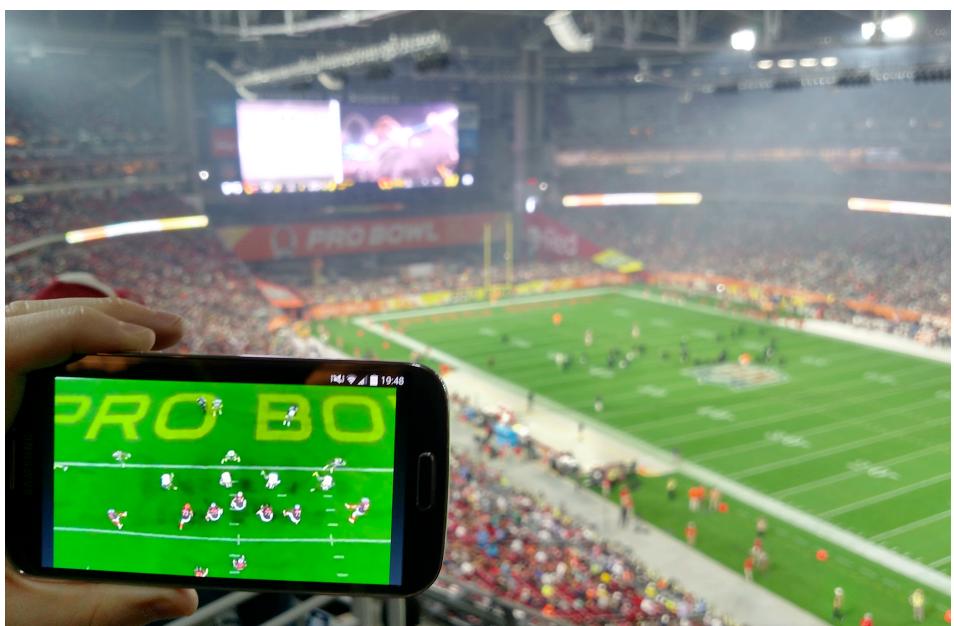
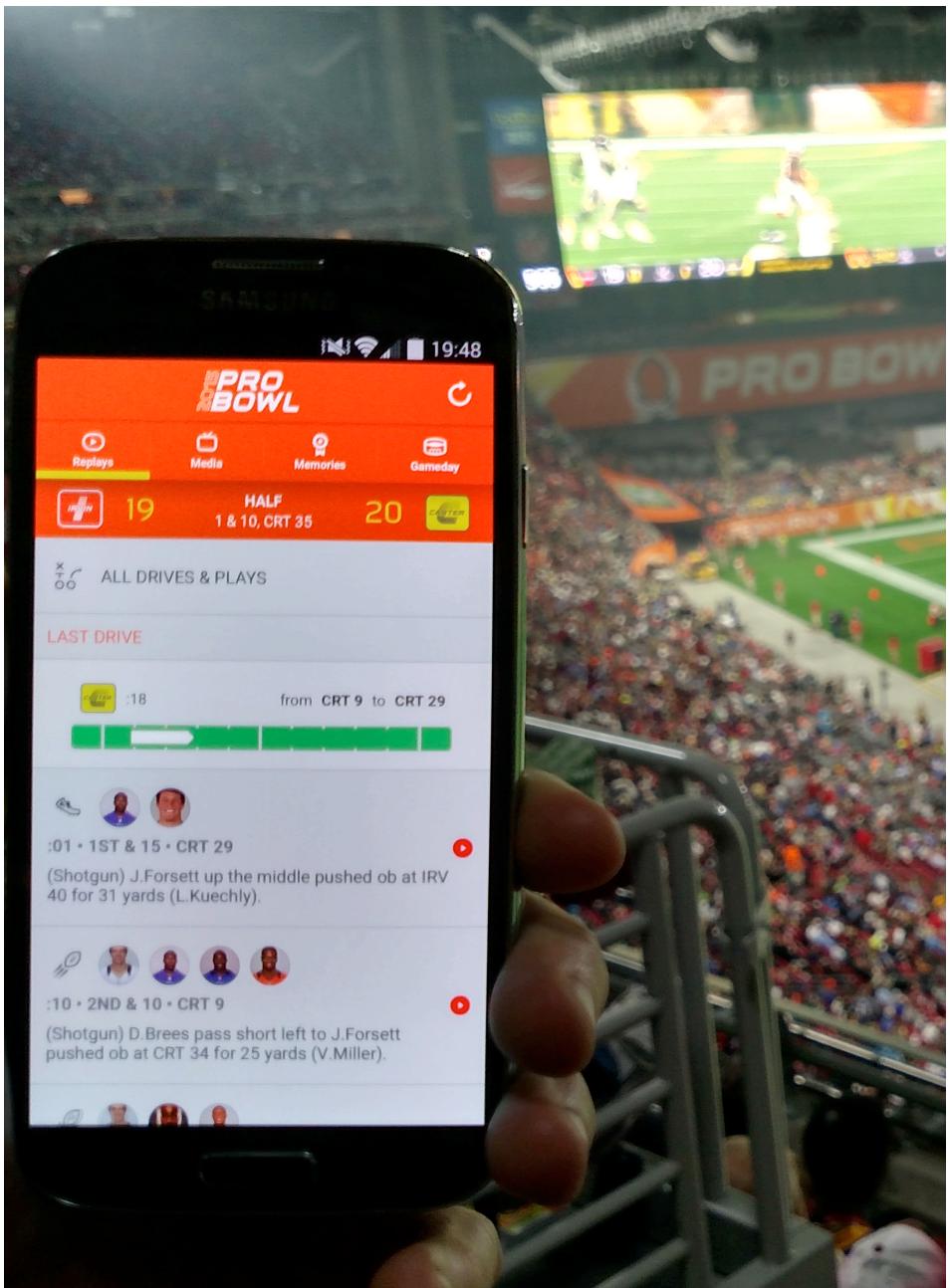
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- Concept invented by Tony Verna in 1963, to improve the telecast
  - Did not receive a patent/payment for his invention
- Army-Navy game, December 7, 1963
  - Verna had quietly brought with him a giant videotape machine  
*Just record the video, and 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)

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To enable automated replay with machine learning.

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

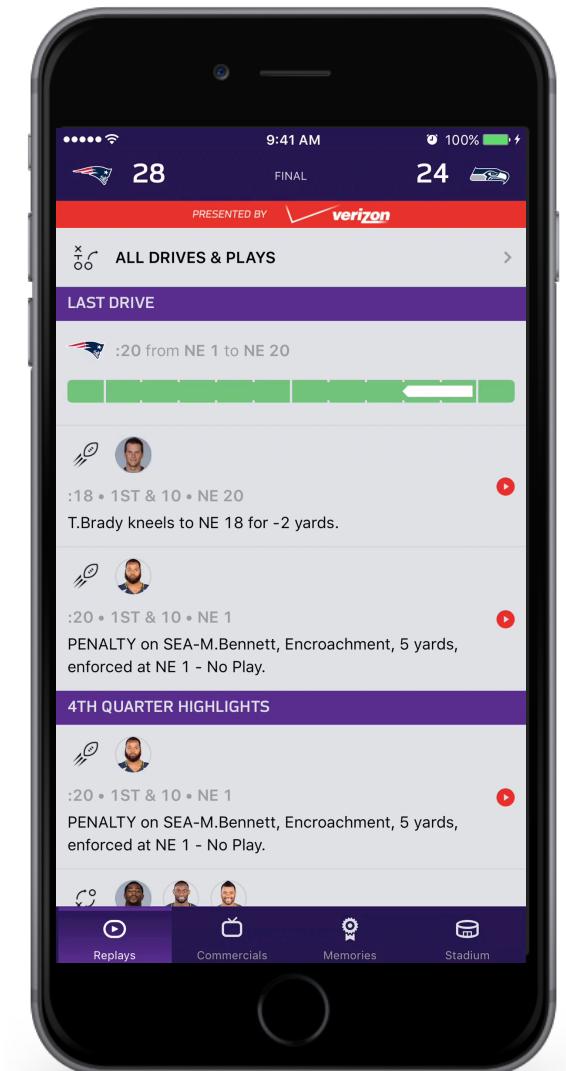
Based on time of play, inbound out of bound, estimate the time to replay

## What does in-stadium wireless enable?

Courtesy: YinzCam, Inc., Pro Bowl 2015

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

# Mobile Replays at the Super Bowl



# The Advent of Bluetooth LE

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- BLE is a wireless personal area network technology
- 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, .....

Most of stadiums today has bluetooth low energy.

Bluetooth is not multihop -- it is singlehop. 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

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- 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

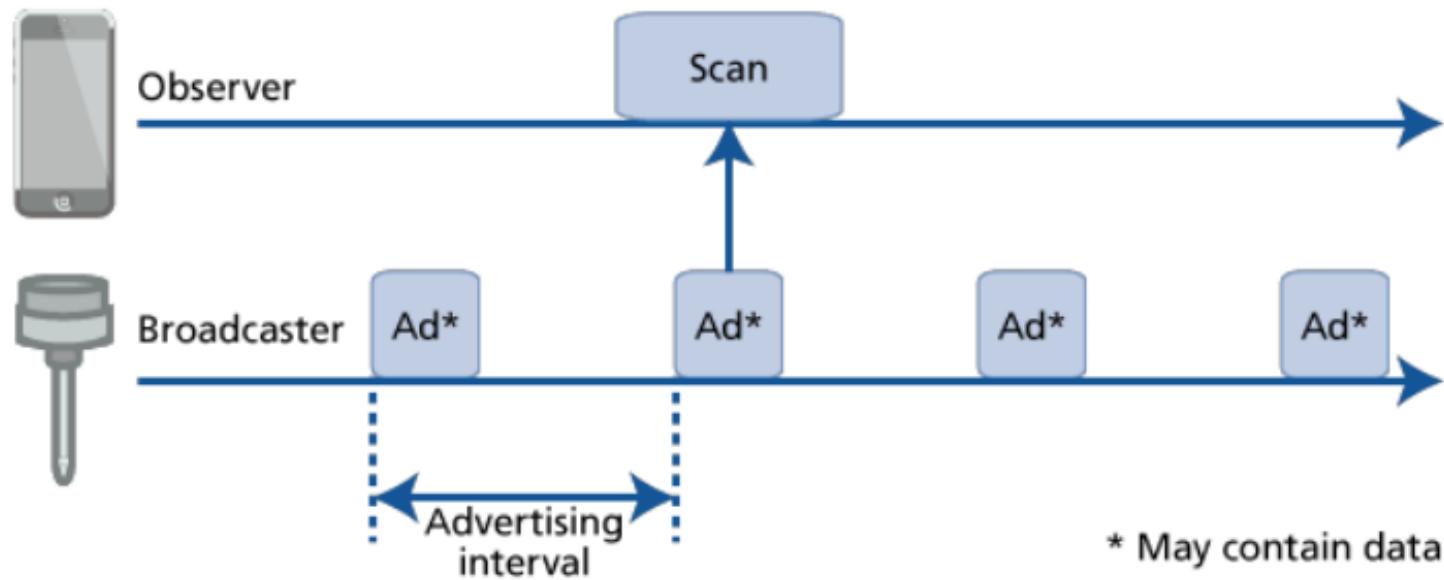
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- Just like Bluetooth, BLE operates in the 2.4 GHz ISM band
- Both do Adaptive Frequency Hopping
- Bluetooth hops across 79 channels at 1MHz each
- BLE hops across 40 channels at 2MHz each
- Unlike classic Bluetooth, BLE remains in sleep mode constantly 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

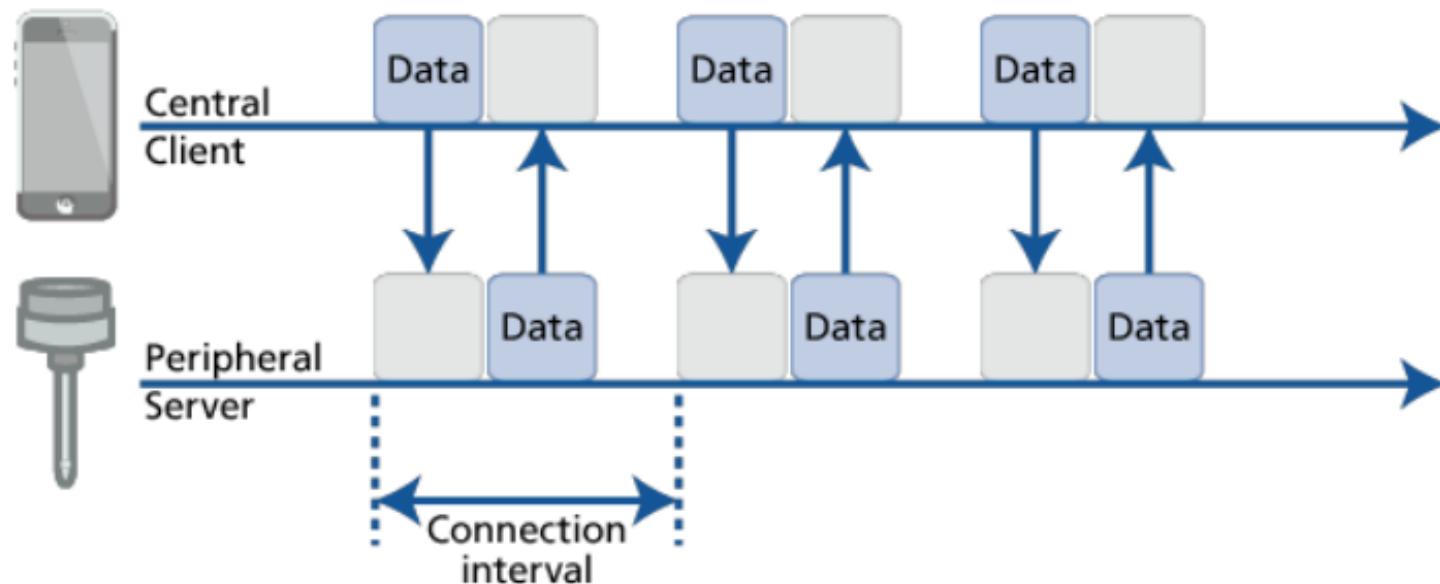
Let the device advertise only once a month.



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

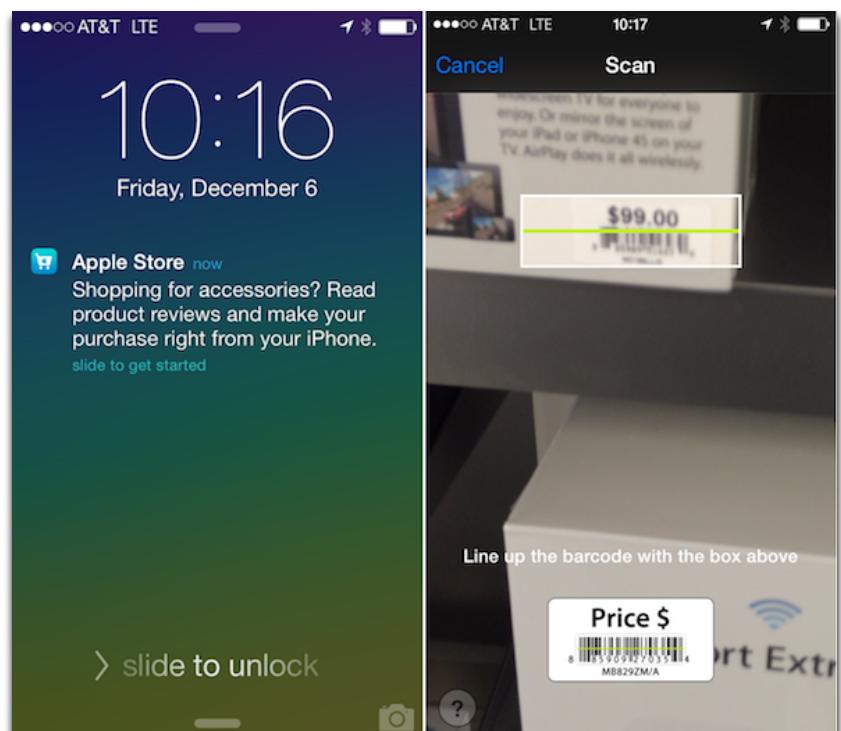
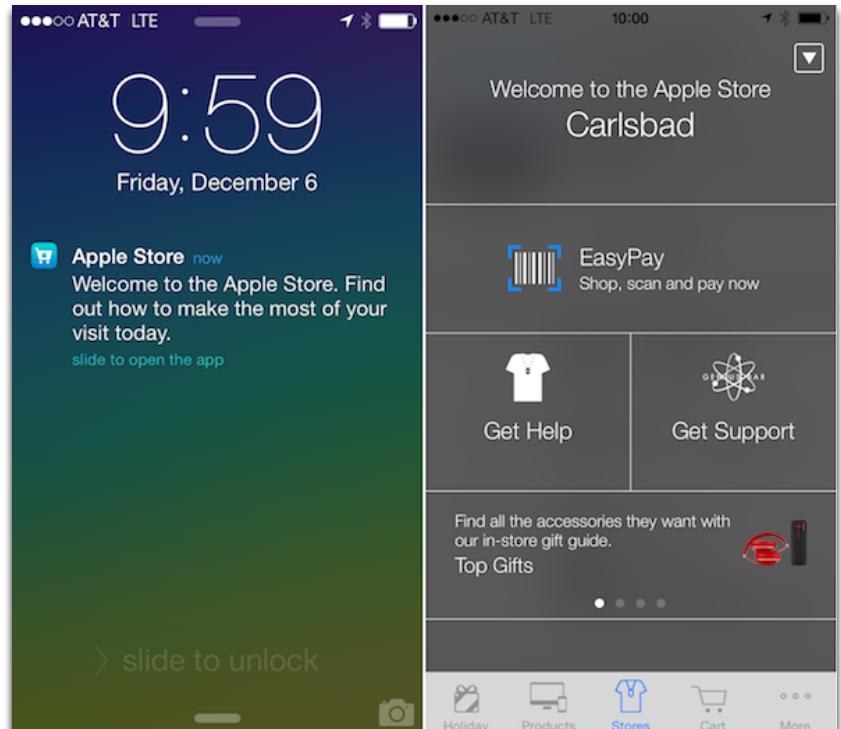
- To reduce **showrooming**

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

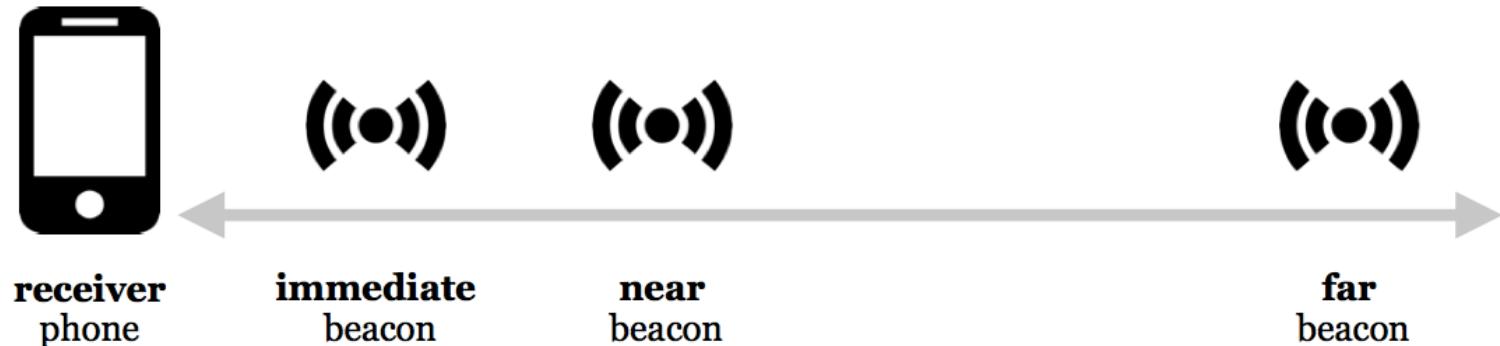
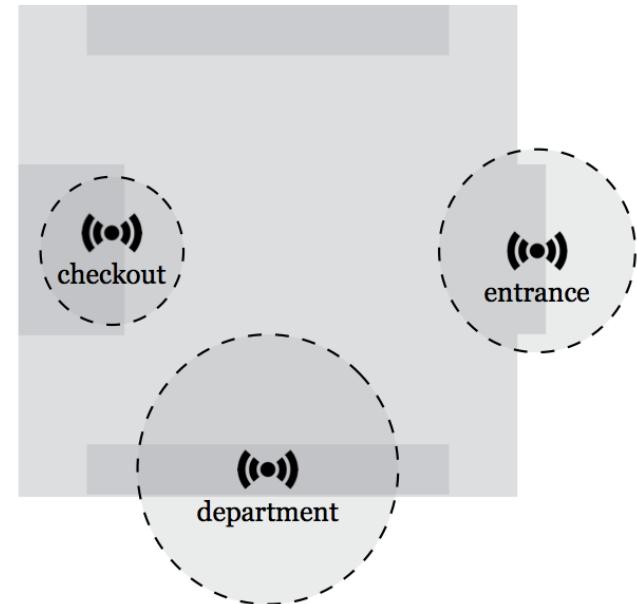
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- **Location** is often represented by a point and a radius
- **Proximity** is the fact that you are close to a specific physical location
- “I’m waiting at the bar”
- “I just entered Gate 3 at the stadium”
- “I’m standing in front of a shelf of jeans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

\$ Both Beacons and NFC can allow you to pay for purchases without touching your wallet. \$



iBeacons have a range of 50 meters.

NFC supports encryption, and the close proximity between devices means the odds of a hacker intercepting the signal is minimal.



iBeacons can last 6 months before the battery needs to be replaced.



Beacons are good for broadcasting general information such as special offers inside a shop, or location data. It can also be used to send personalised messages and recommendations based on location or transactional history.

Beacons have the potential to be invasive, acting like real-world pop ups that trigger when you walk within range.



NFC has an optimal range of 4 centimeters.



NFC requires no power to function.



NFC requires a person to choose to engage with it in order to work, making it a very personal interaction. Because of this, NFC can be used to request specific data, such as additional information on a specific product.

BLE ~= 20 feet away, NFC needs to touch.  
NFC = proximity based protocol.

# Beacons vs. NFC

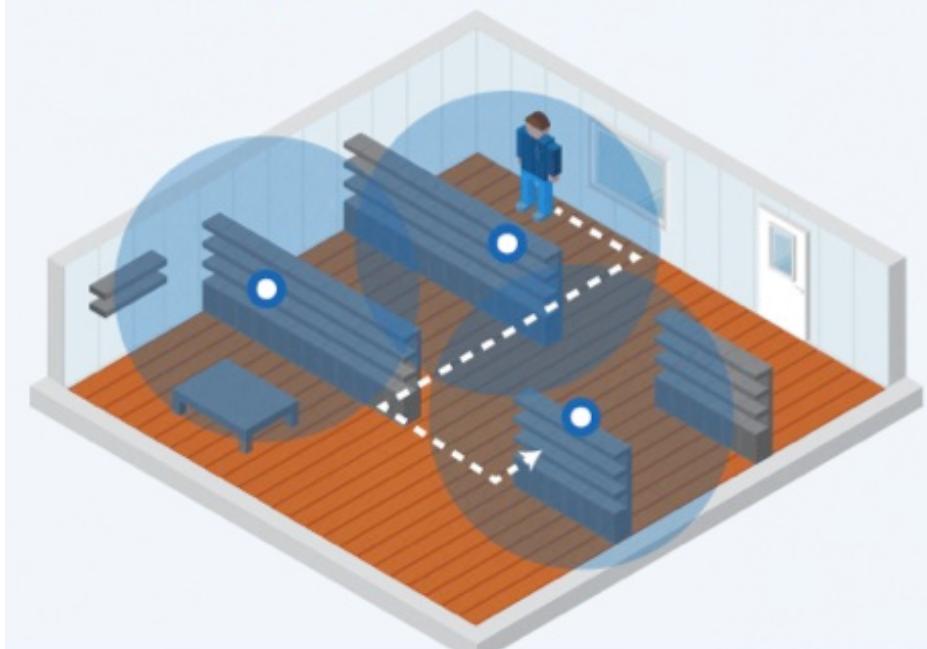
- BLE Beacons continually transmit a discovery signal received by BLE-enabled smartphones
- NFC tags only communicate when close to an NFC-enabled smartphone
- BLE beacons' coverage radius can be multiple feet/meters
- NFC tags' coverage radius is centimeters

Proximity-based Micro-location.

Wireless transmitter's (NFC Tags) coverage radius is very small.  
Measured in centimeters.



Wireless transmitter's (BLE Beacons) coverage radius varies according to signal strength. Measured in Feet.



# Here a Beacon, There a Beacon

The Hitchhikers Guide  
to iBeacon Hardware.

A Comprehensive Report by Aislelabs



Accent Systems



April Brother



BlueSense



Estimote



Gimbal Series 10



Gloworm



Kontakt.io



KSTechnologies



Minew



Roximity



Radius Networks



RECO Beacon



RedBear



Sensorberg



SensorTag

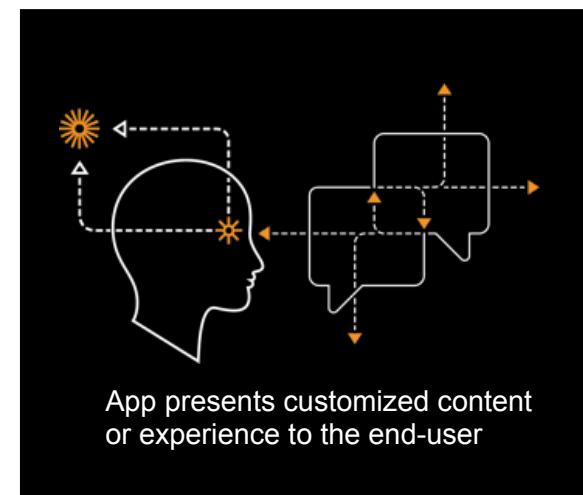
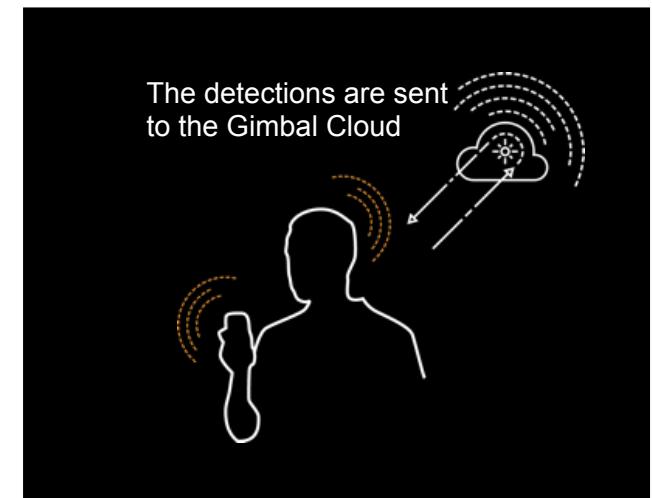
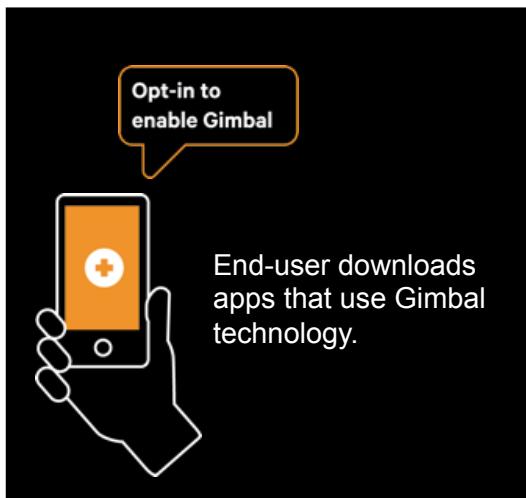


Tod

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?

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





**CONNECT PHYSICAL TO DIGITAL**

Several industries are using beacons to change the game

# Domains of Interest

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**STORES**

Deliver in-store offers and e-catalogues to target shoppers



**RESTAURANTS**

Attract new customers with coupons while offering returning customers express pre-order and pick-up services



**SHOPPING MALLS**

Guide visitors with floor plans, events, and the hottest sales for a boost in traffic and revenue



**AIRPORTS**

In addition to flight information, showcase duty-free promotions and special vacation deals



**STADIUMS**

Send welcome messages, seat maps, and coupons for snacks and sporting goods



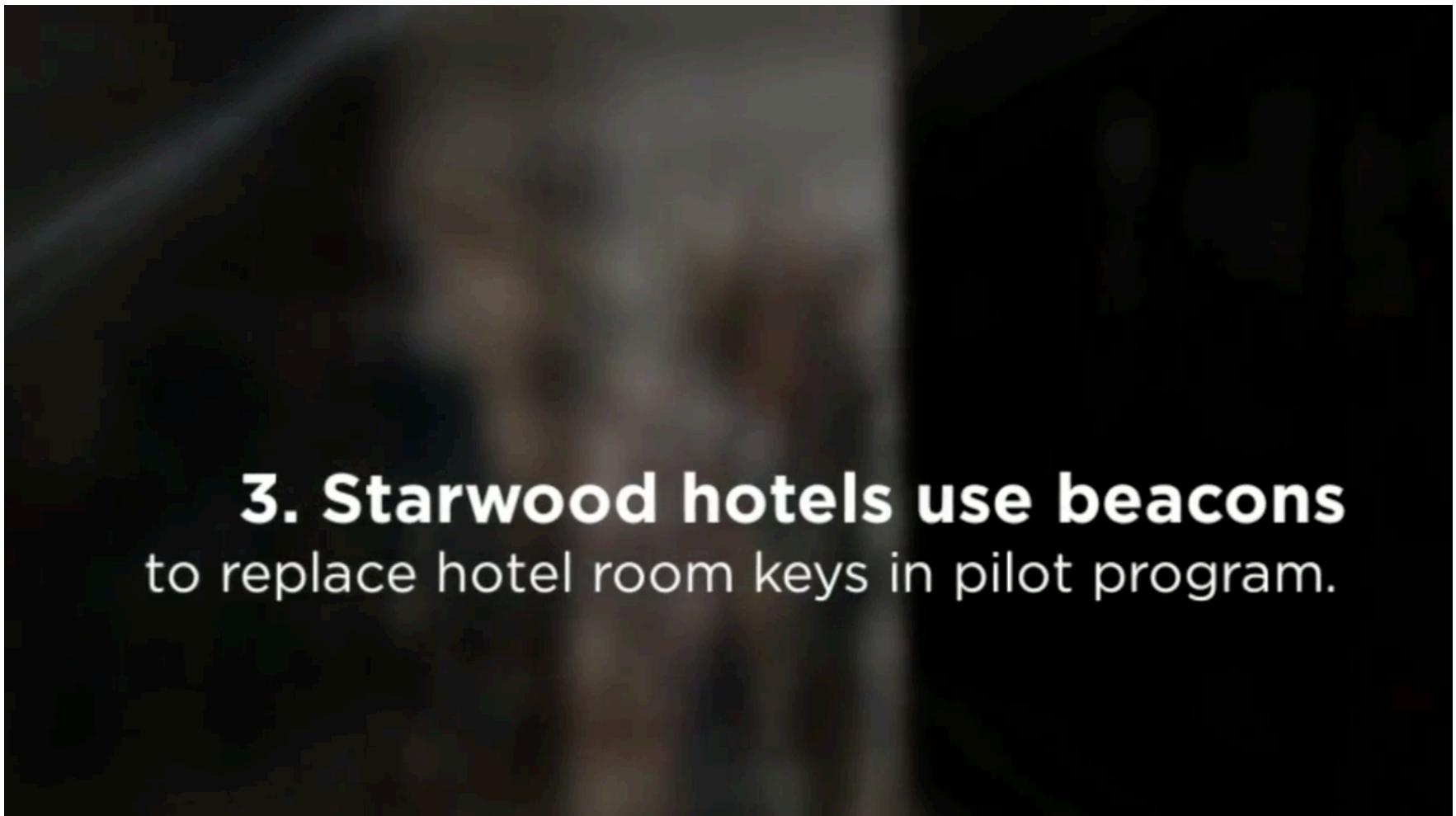
**MUSEUMS**

Provide mobile tours for exhibitions as well as museum shop promotions

Self-guided museums.

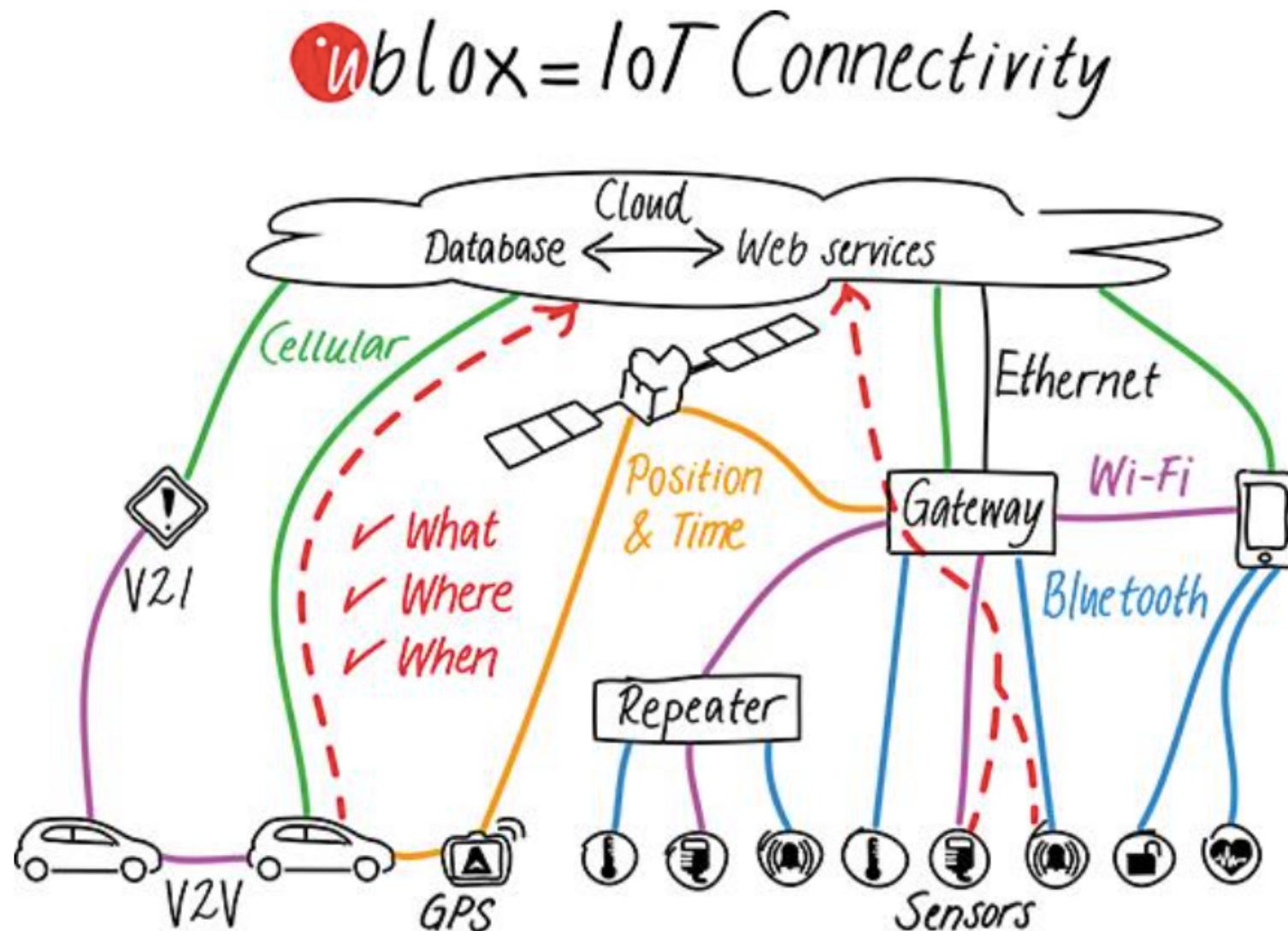
# Domains of Interest

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**3. Starwood hotels use beacons**  
to replace hotel room keys in pilot program.

# How everything works together

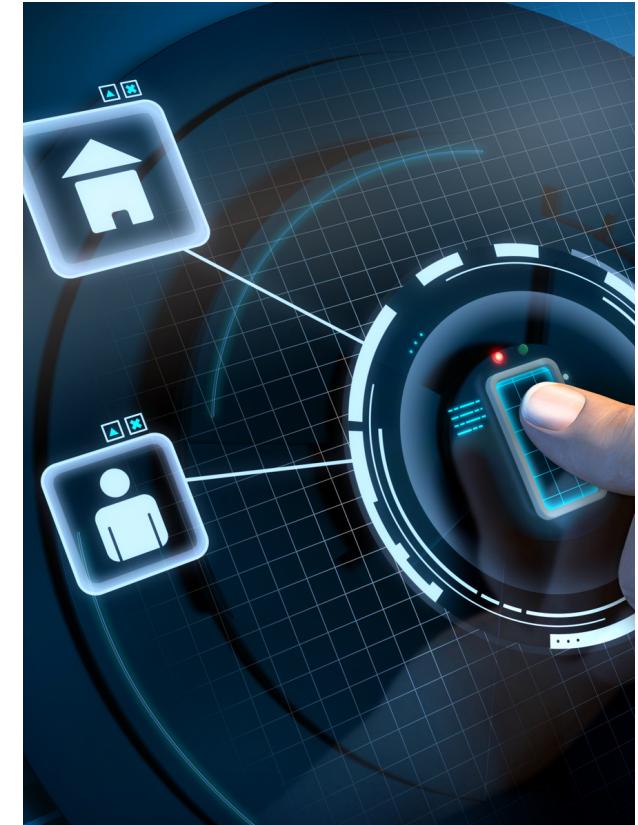




Retail (65%)



Travel & Sports (30%)



Home Automation (5%)

400M beacons out there (as of May 2014)

# Airline Industry

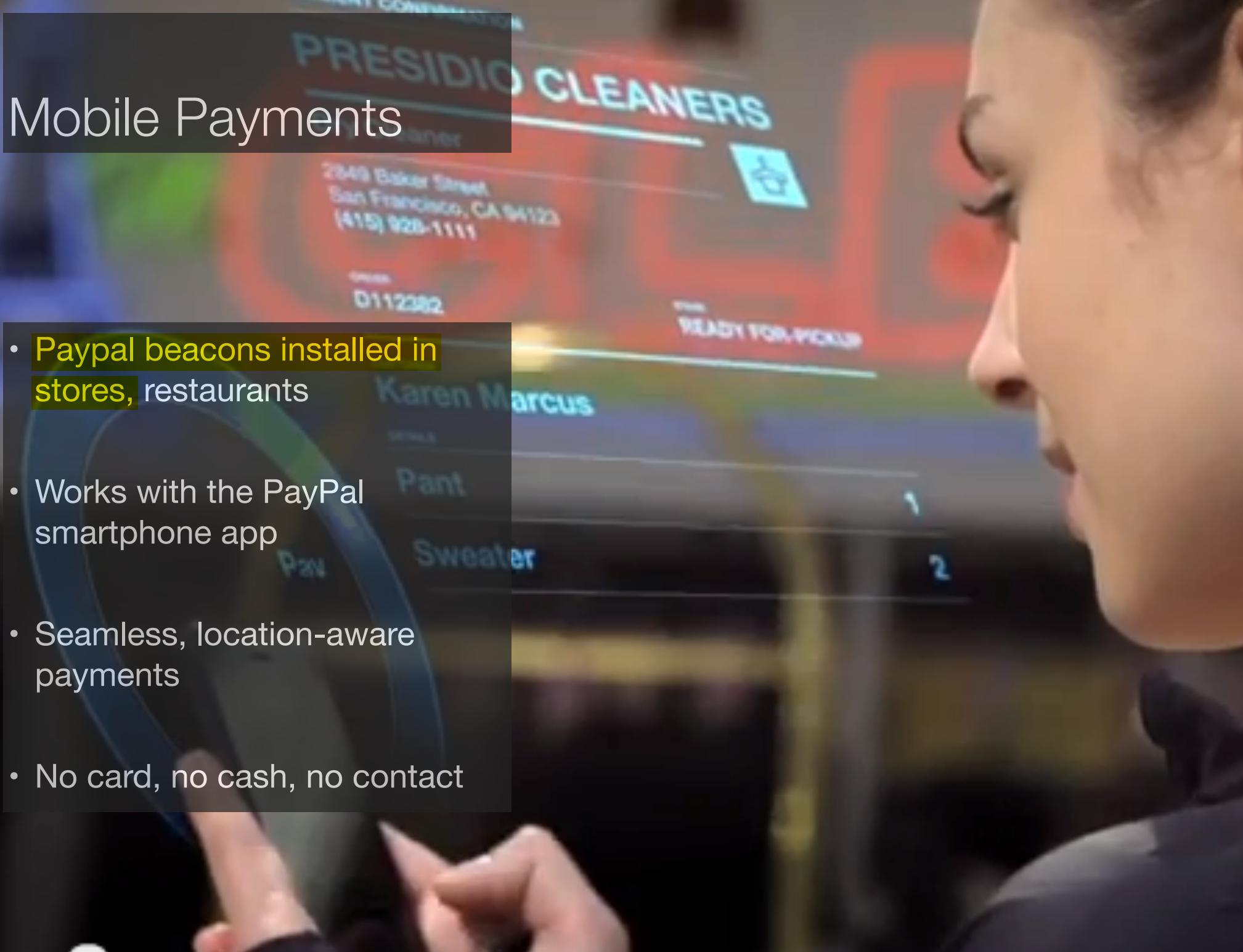
- Virgin Atlantic trials in Heathrow Airport club area
- Information about flights, delays
- Reminders for boarding
- Reminders of perks

The lounge is BLE enabled.

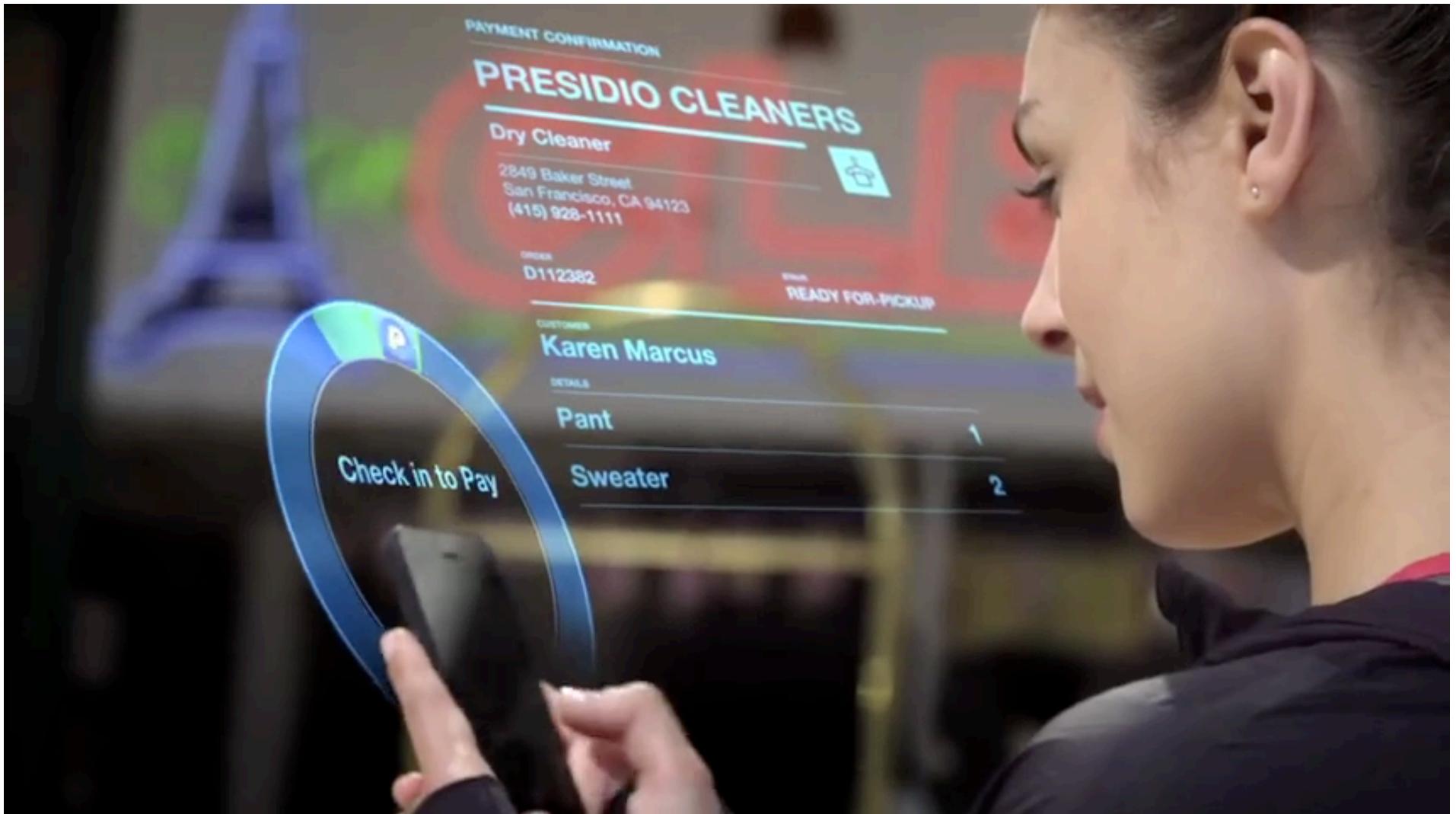


# Mobile Payments

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



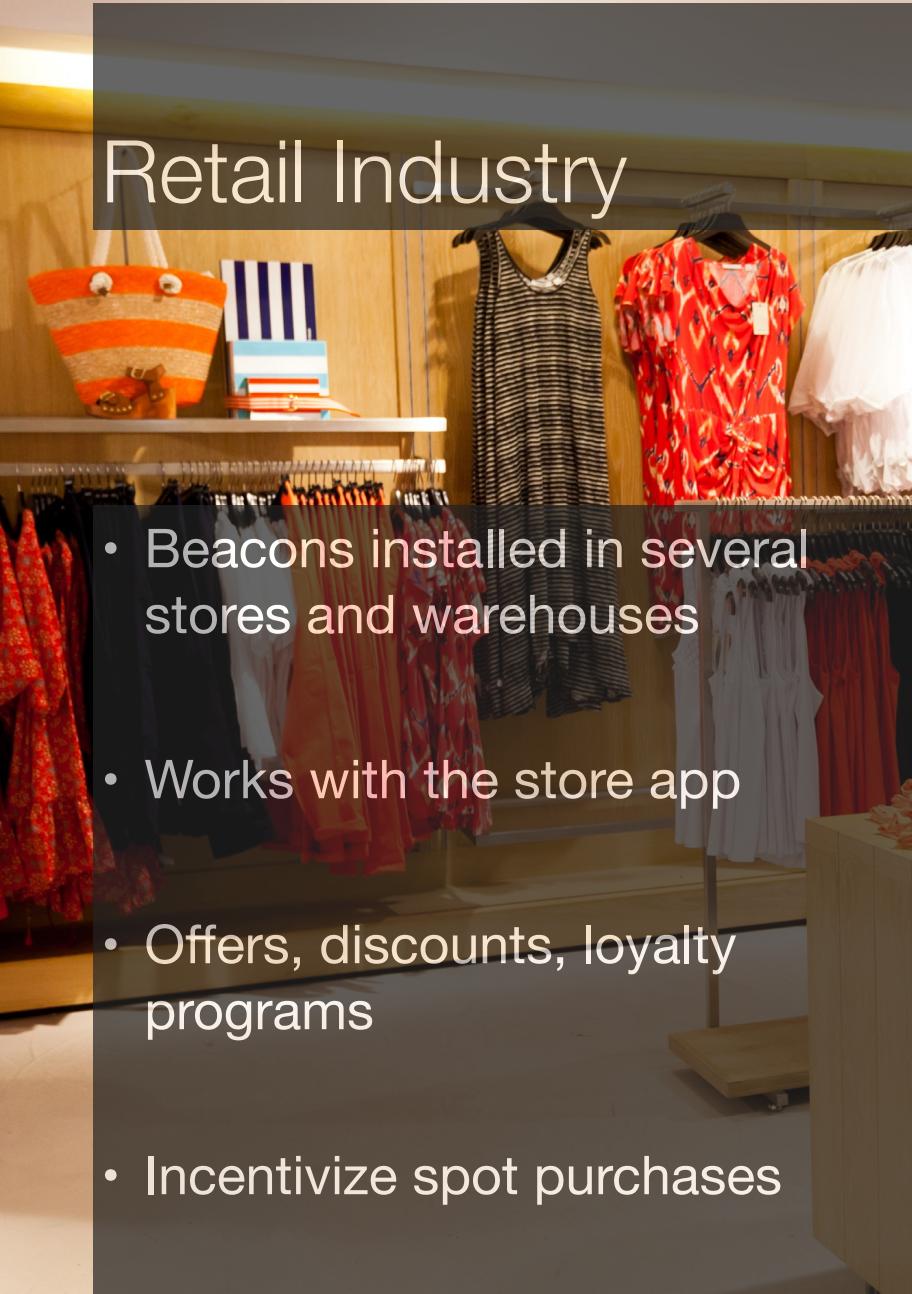
Mobile Payment with Beacons are happening in the stadiums everyday.

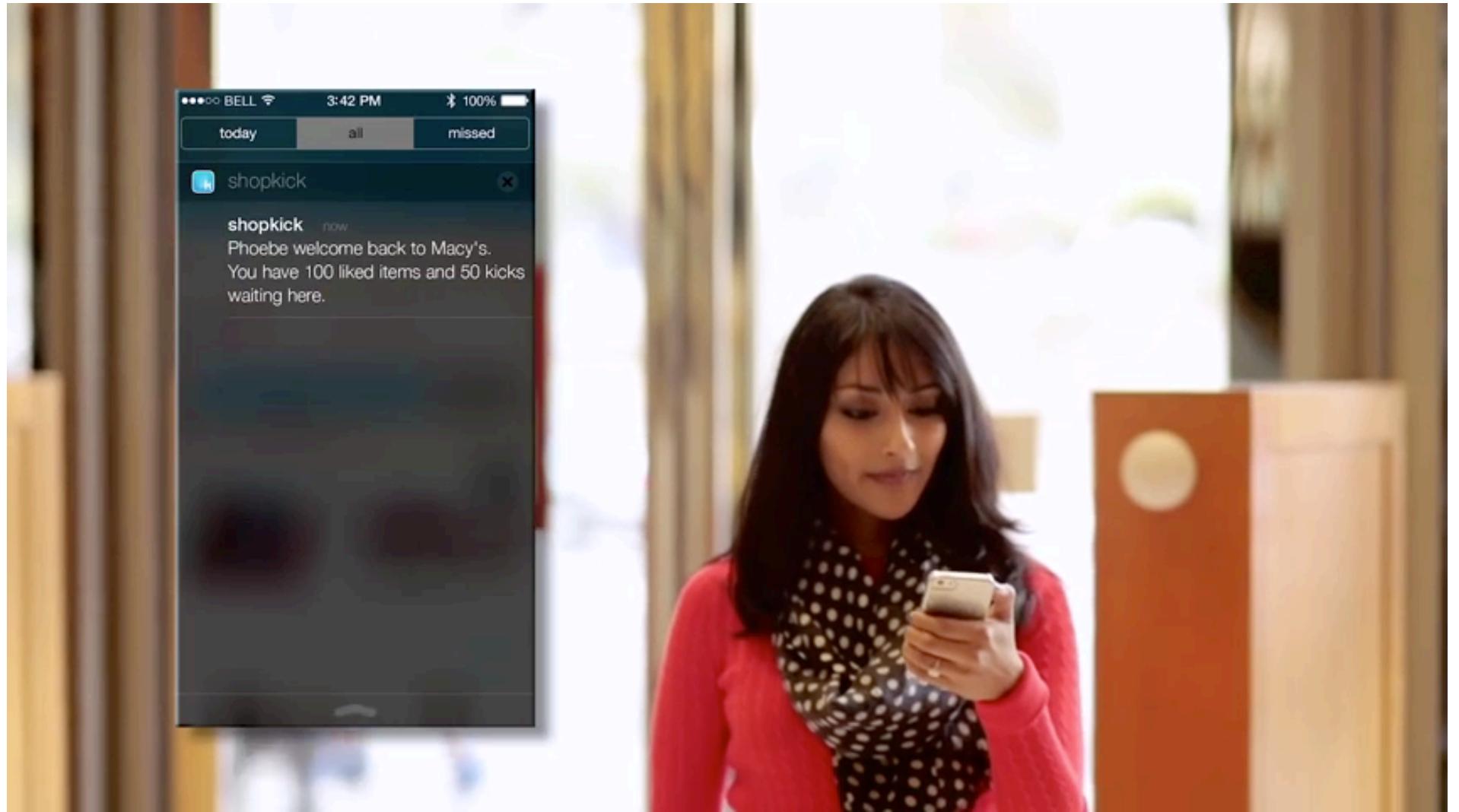


## Mobile Payments

# Retail Industry

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

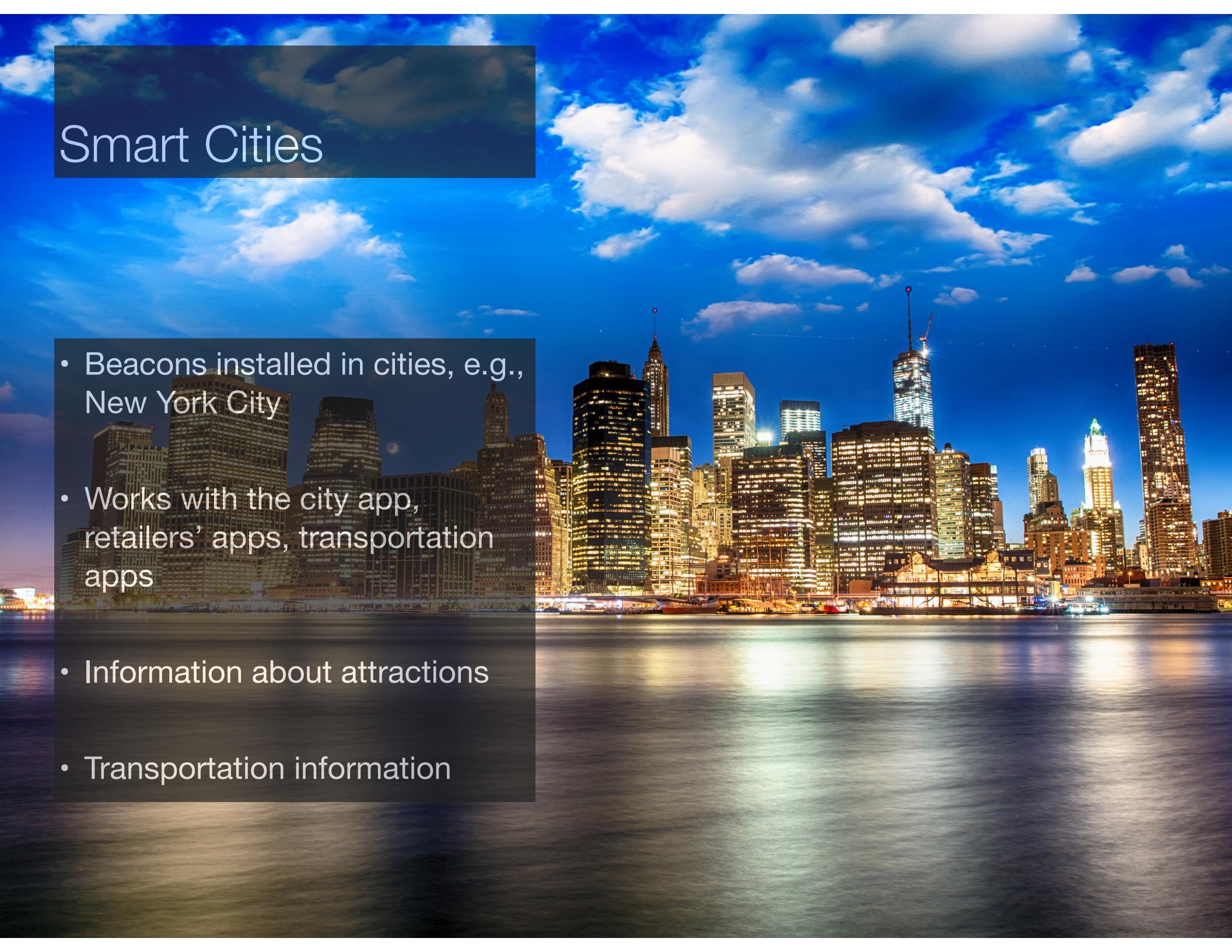


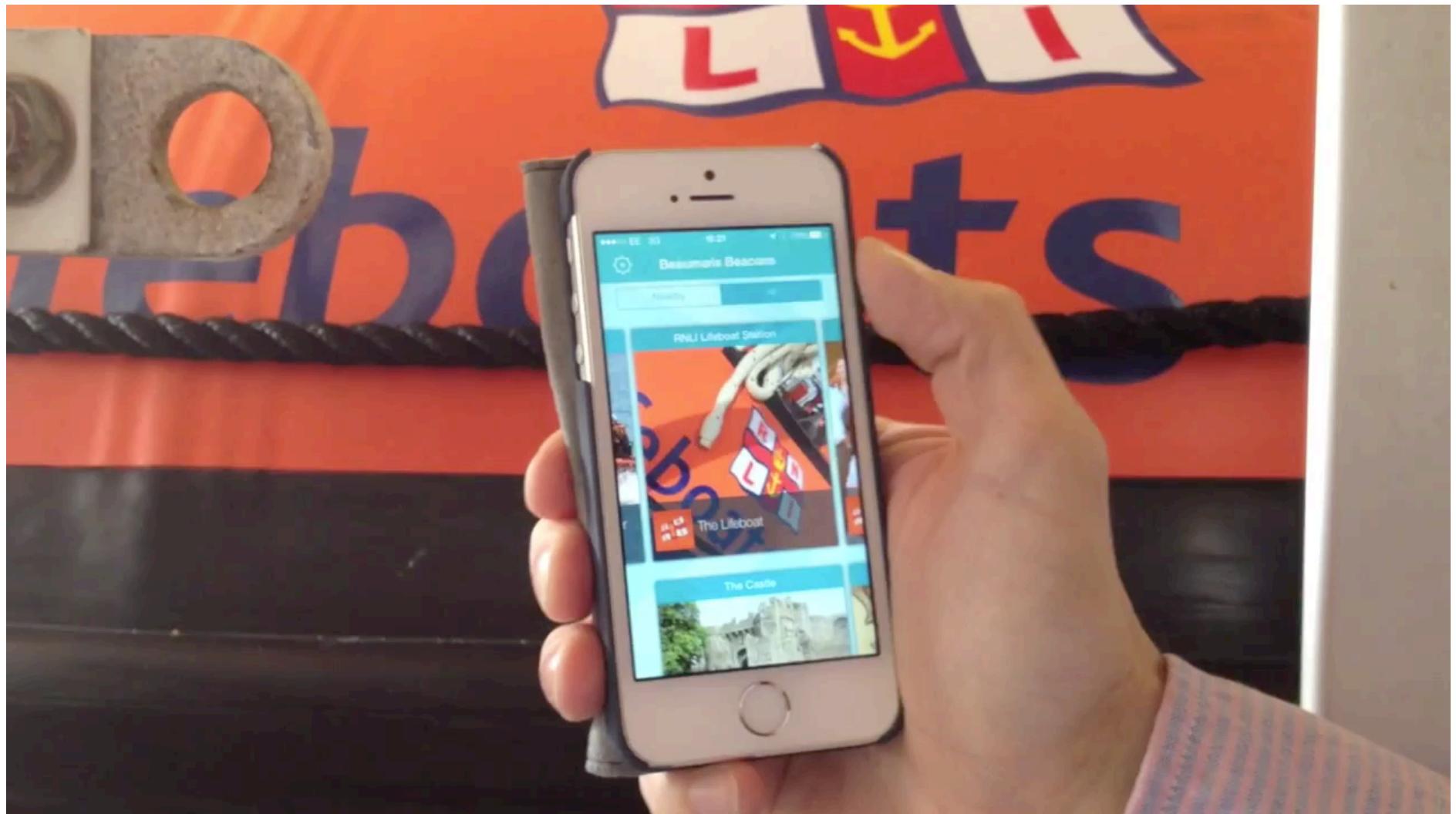


## In-Store Experiences

# 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



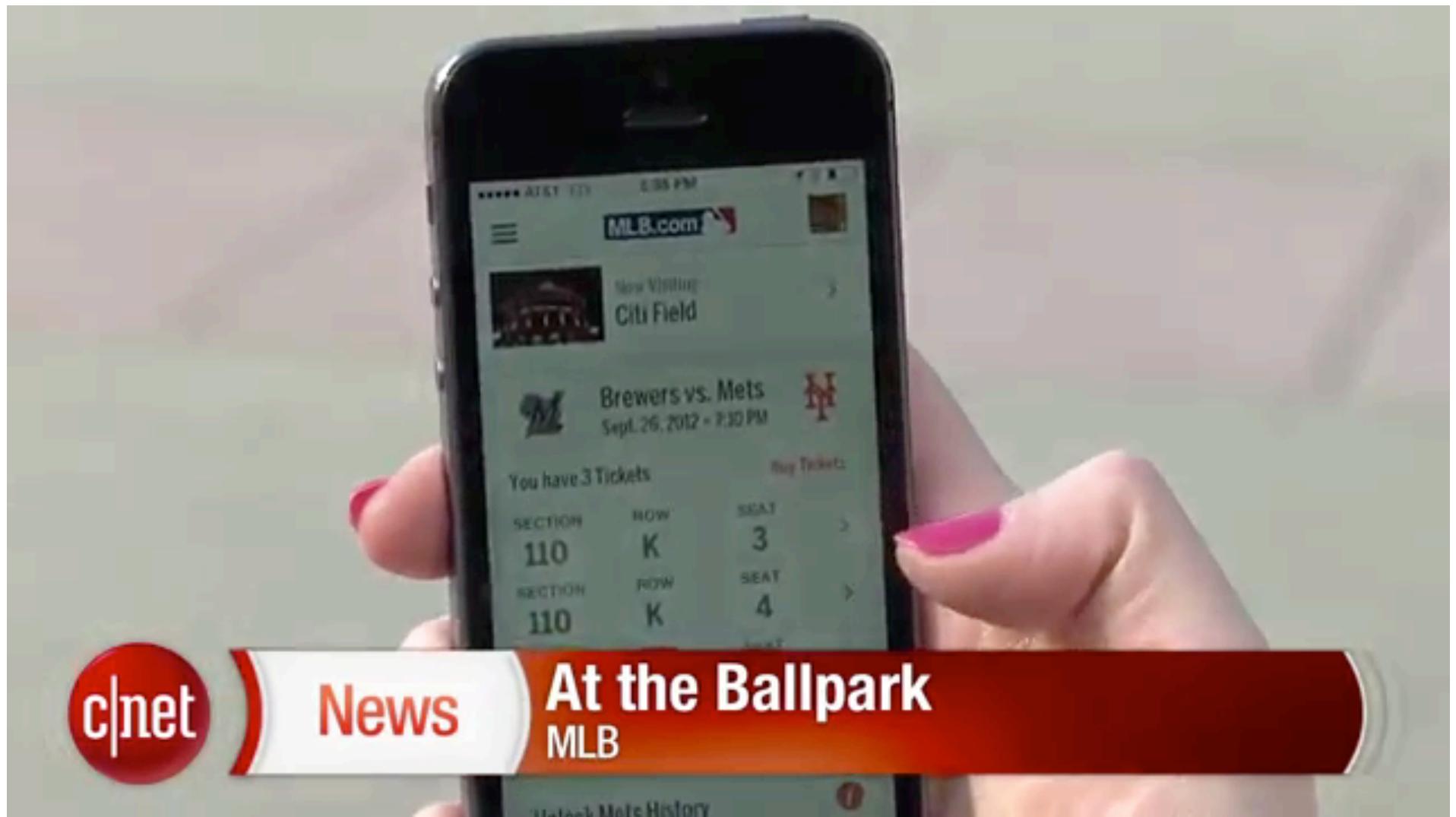


In-Store Experiences

# 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





News

## At the Ballpark

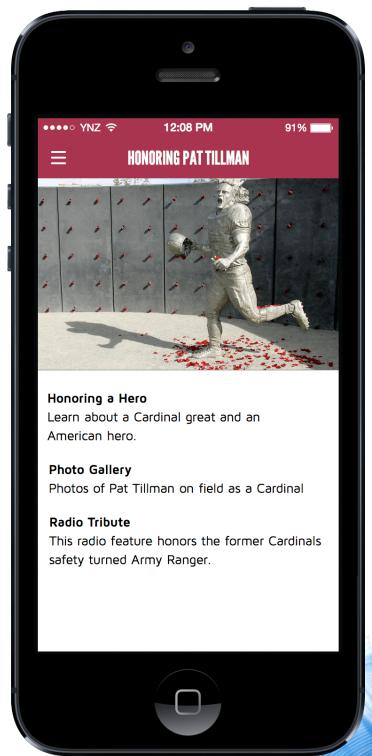
MLB

Interactive In-Stadium Experiences

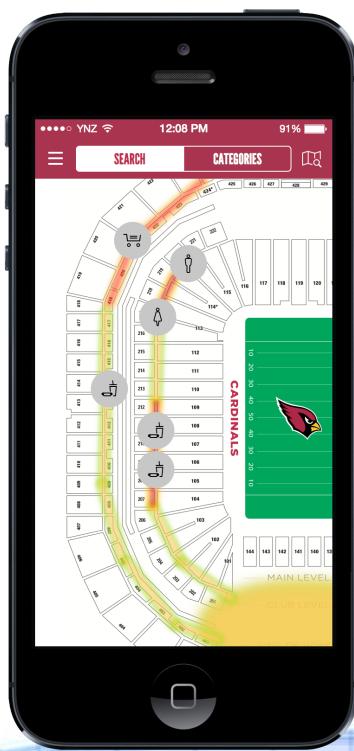
Out-of-stadium  
ingress, egress &  
parking congestion



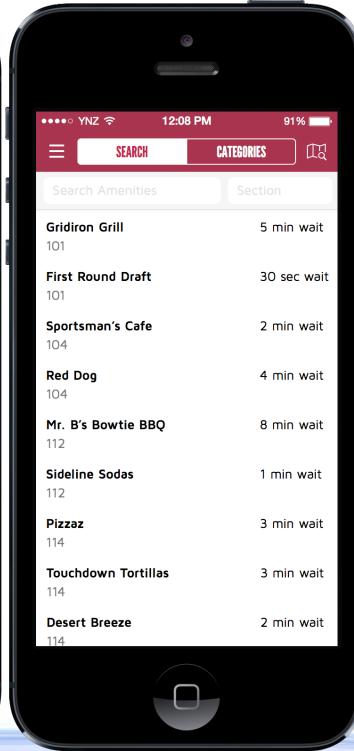
Interactive exhibits



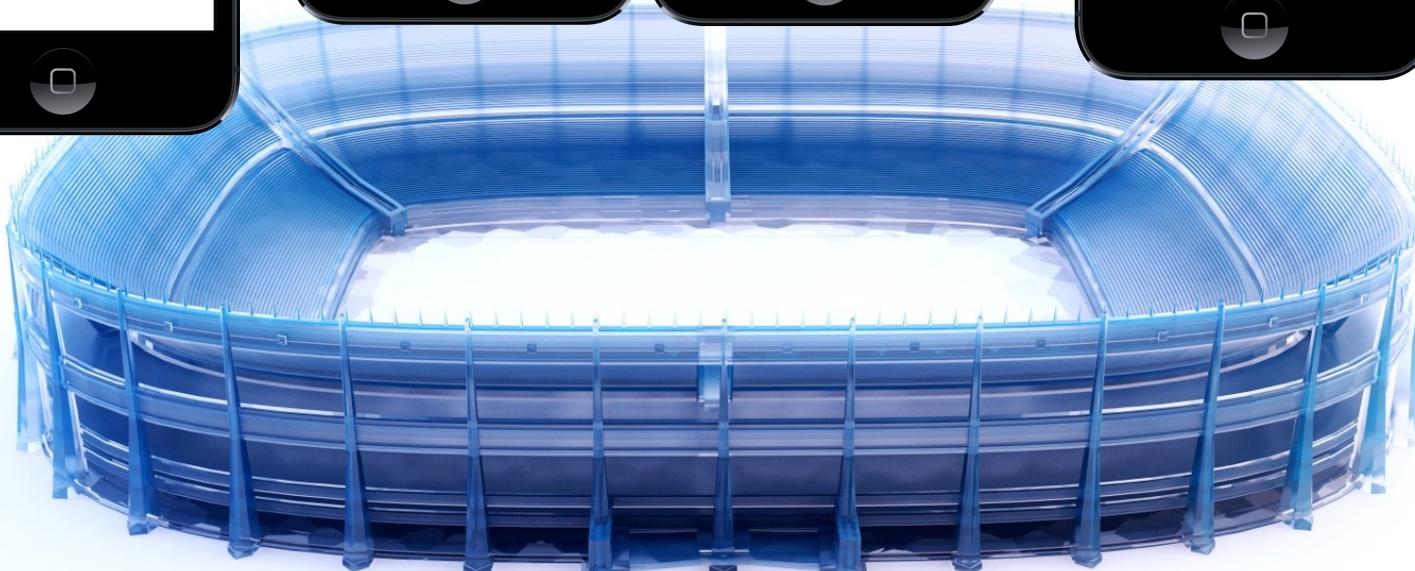
In-stadium congestion



Wait-times



VIP areas



Beacon-Activated Fan Journey

# Check-ins

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- ◆ 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 longitude 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”

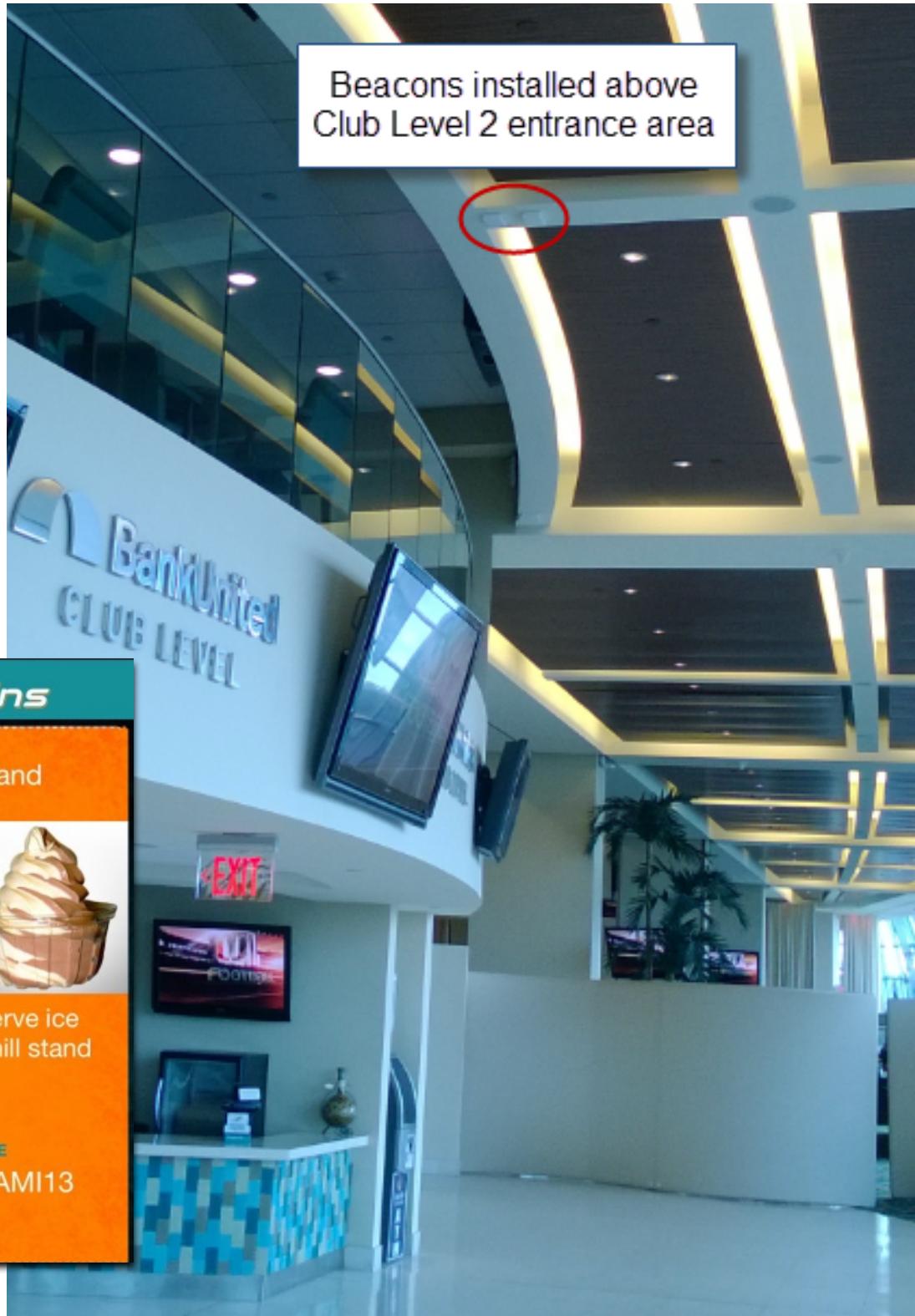


The advertisement features the Miami Dolphins logo (a dolphin leaping out of water) and the text "Team Store". It shows a player in a teal jersey with the number 17. The text "10% off discount" is prominently displayed. Below it, the text reads: "Get 10% off any Miami Dolphins Jersey at the Team Store in Sun Life Stadium." To the right, there are sections for "EXPIRES" (09/17/13) and "CODE" (MIAMI13), each with a blue "UP" arrow icon.



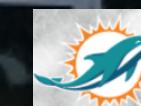
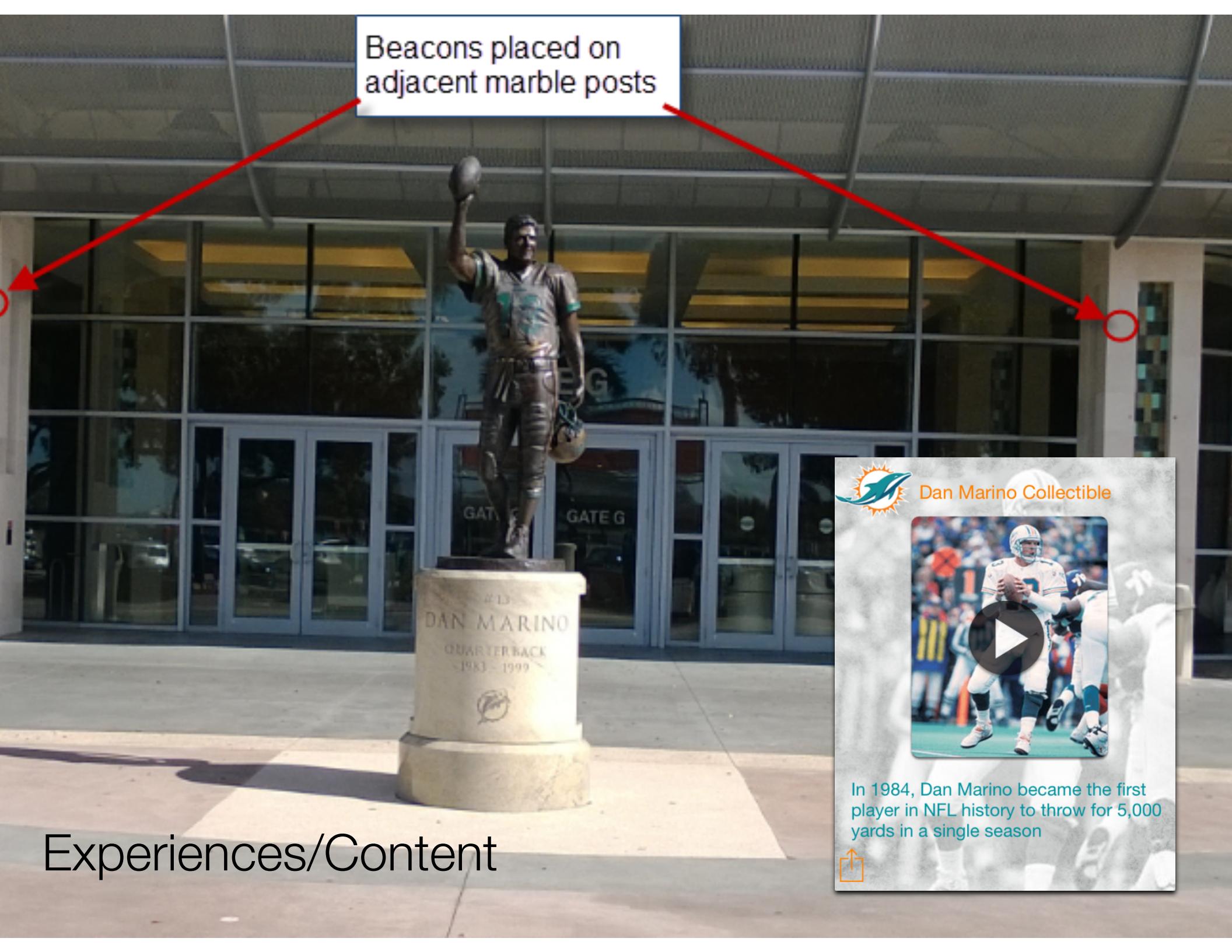
# Line-Busting

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



Beacons installed above Club Level 2 entrance area

Beacons placed on adjacent marble posts



Dan Marino Collectible



In 1984, Dan Marino became the first player in NFL history to throw for 5,000 yards in a single season



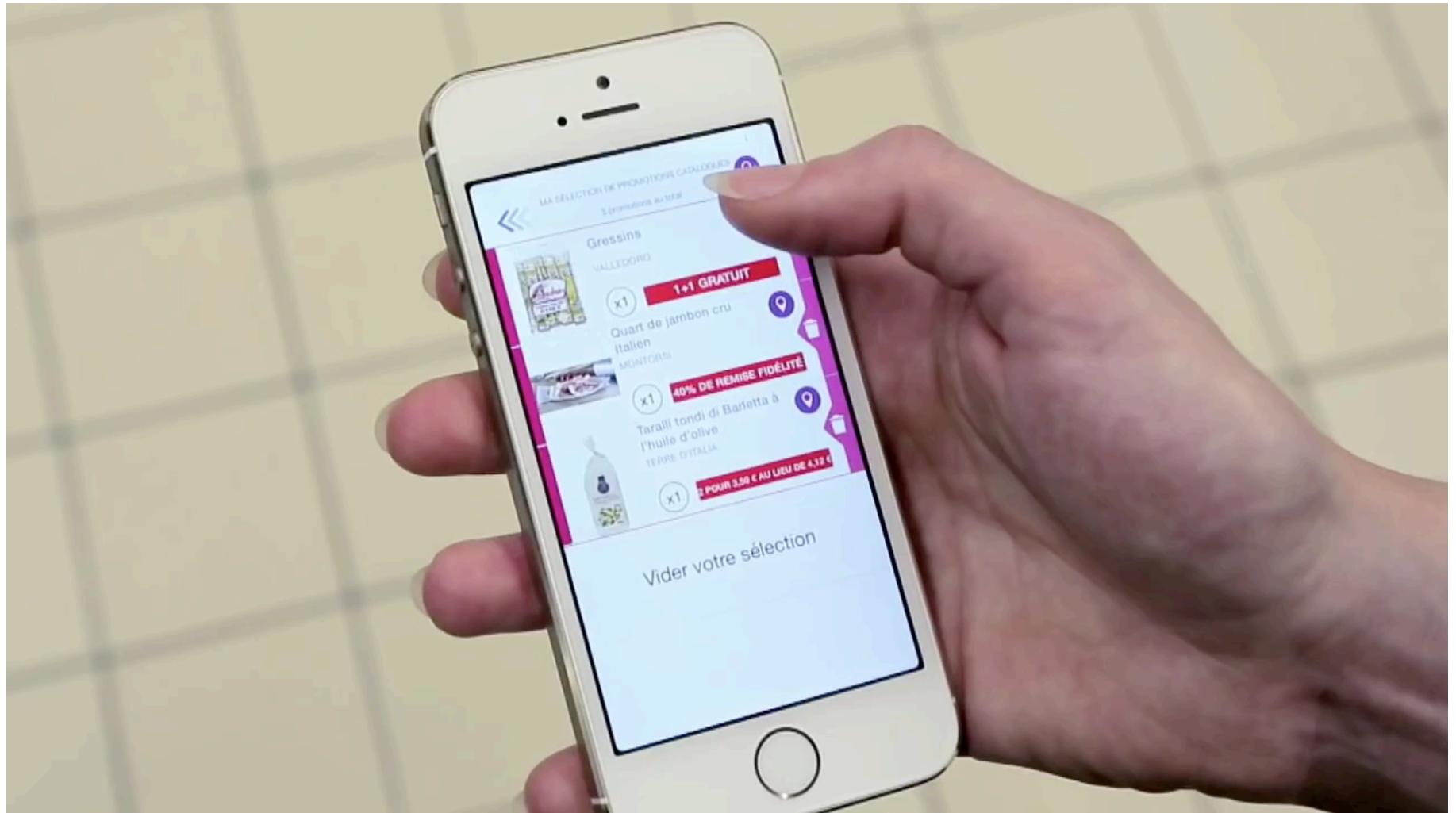
## Experiences/Content

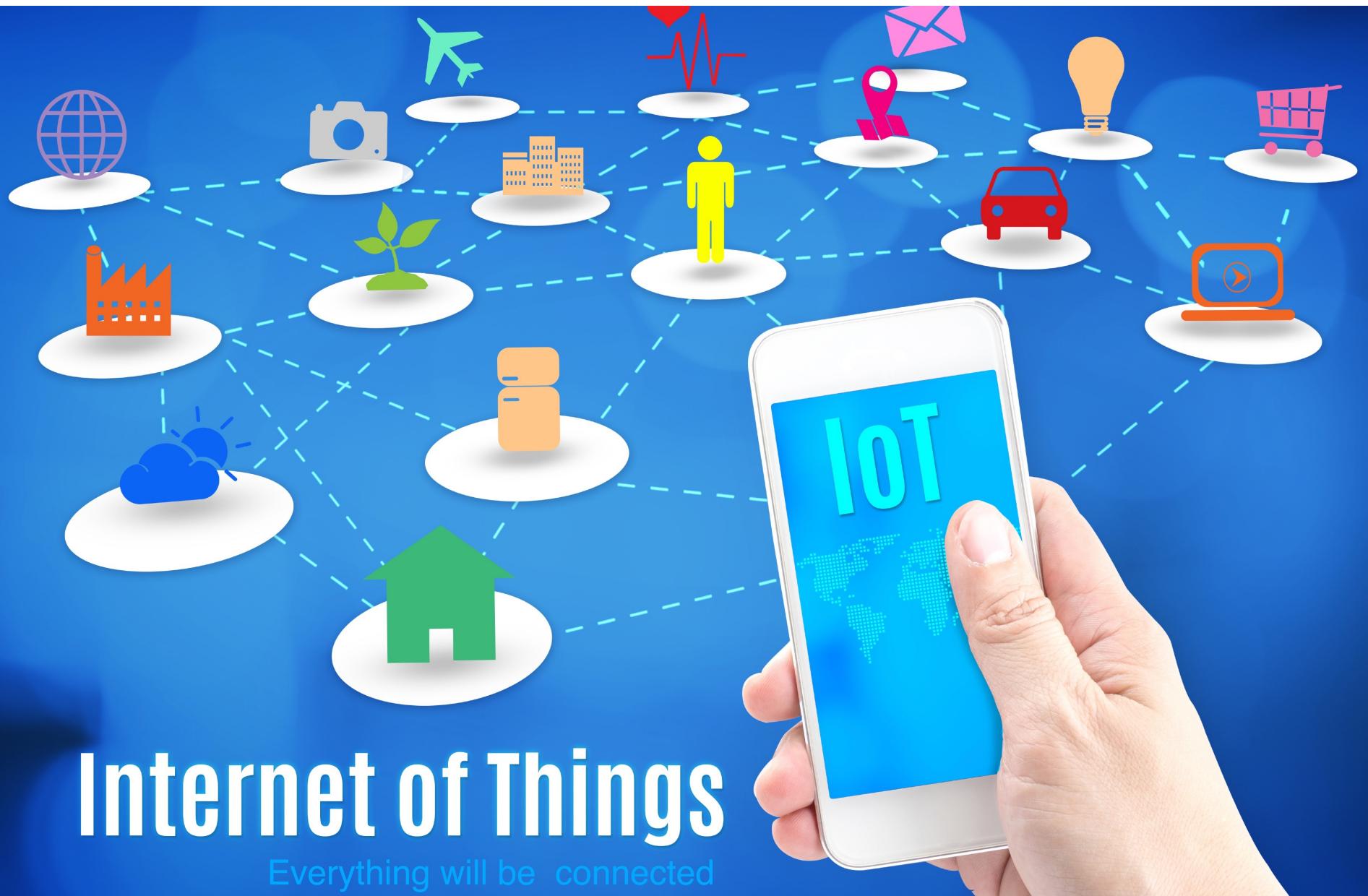
# Competing Technologies (Visible Light)



# Competing Technologies (Visible Light)

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# Internet of Things

Everything will be connected

The Stadium of the Future  
18-738 Sports Technology

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