Technology Institute

Mobile Innovations Forecast

Sensing and making sense: Device and environment underpin contextually aware services

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The core building blocks for contextual awareness and intelligence emerge from understanding the immediate situation of an end-user. Knowing a user's physical location, time-of-day, calendar and data associated with movement of the mobile device captures a large swath of information required by predictive algorithms that make contextually relevant suggestions or automatically execute actions on behalf of the user. This situational device data, in turn, will be augmented by visual and aural information to develop more nuanced, semantically rich descriptions of a user's current environment and likely intent.

To accomplish this, the technology industry is already in the midst of a race to connect mobile devices and their physical environments with sensors, beacons and other data gathering and broadcasting technologies. Not just smartphones and tablets, but fixed locations and everyday objects are gaining the ability to communicate wirelessly with each other and with the end user. PwC expects this race to accelerate.

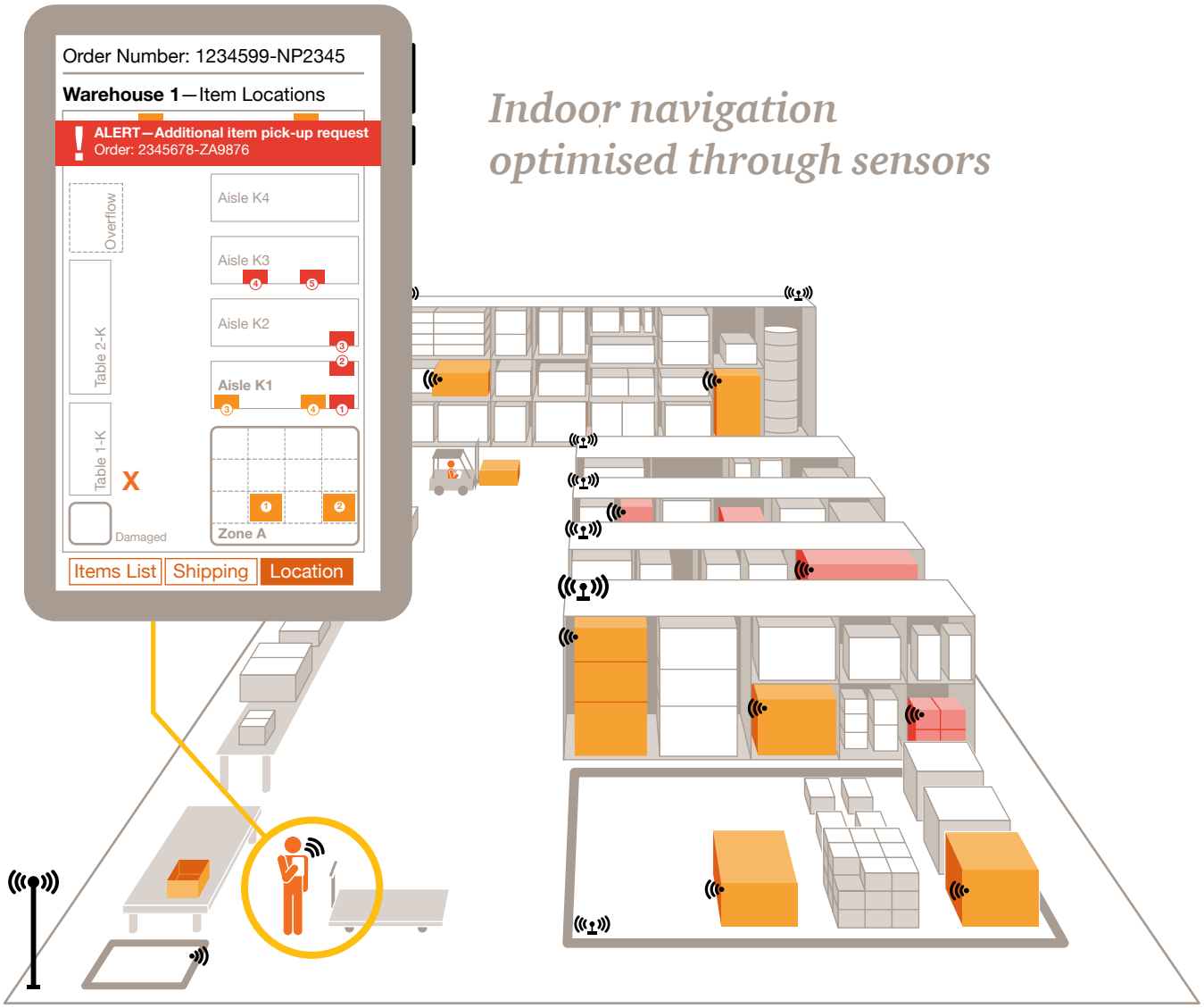
This article focuses mainly on physical context information harvested and packaged by accelerometers, gyroscopes and other mobile device sensors that create a picture of the state of the device. Cameras and microphones are

Phase II synopsis

This is the second article in the *Mobile Innovations Forecast Phase II: New Technological Capabilities*. Here's a roadmap of the series:

- The Introduction argues that the dominant drivers of mobile innovation to 2018 will revolve around capturing and modeling the contextual situation of mobile users, and will transform the mobile device into an intelligent digital assistant.
- **This second article focuses on how device and environmental sensors interact to capture information to model the user's physical context.**
- The upcoming third article will examine the communications network that will enable information from the physical environment to be correlated in the cloud to create the virtual context layer of the user experience.
- The fourth article will describe the modeling and analytics, mainly in the cloud, that will enable the mobile device to become as intimate as a close friend, if you allow it.
- A concluding article will highlight the most significant new capabilities driving smart devices towards true digital companionship, setting the stage for new use cases and business models to follow. ■

Figure 1: The interactive warehouse



also significant sensors. However, their utility for generating a contextual model of the end user is tied more to image and audio recognition applications that live in the cloud. Analytic capabilities that make sense of captured images or audio will be explored in the fourth article of this series. (see Synopsis)

Most of the low-level technology 'conversations' between the physical world and the user's mobile devices will take place at the sensor level. In addition to continuing improvements in sensors themselves, new capabilities for understanding physical context are evolving in these areas:

- dedicated processors for contextual awareness
- sensor fusion, which turns data from multiple sensors into usable information
- new frameworks for security in peer-to-peer or *ad hoc* networking
- geo-fences, which are virtual boundaries for physical areas.

Mobile device sensors already respond in rudimentary ways to changes in a user's physical context. Turn a smartphone or tablet from portrait to landscape orientation and the display automatically refits an image. Bring a smartphone to your ear and a proximity sensor tells the main processor to shut off the touch screen. But these limited, primitive examples of individual sensors adapting a mobile device's behaviour around a user's context are giving way to multiple sensors working together to paint a rich picture of a user and his or her environment.

This evolution is in line with the Introduction to the *Mobile Innovations Forecast Phase II: New Technological Capabilities*, which asserts that mobile devices are evolving into contextually smart digital assistants. A big part of that transformation involves enabling mobile devices to understand the physical situation of the end user and employ that knowledge to serve her needs, often without requiring the person to state them explicitly.

Practically speaking, the contextual messages being communicated about physical context by people, objects and locations can be boiled down to "This is who and/or what and where I am right now, and based on my calendar information where I expect to be in the near future." ID signals and beacons within user devices or embedded in the outside world or places and objects capture and communicate who and/or what. Device and environmental sensors capture and communicate location and activity as it relates to use of the device or mobility of the user.[See Figure 1]

As more sensors spread into more devices, places and objects, the smartphone is emerging as the core interface between a sensor-connected world and those who live in it. The physical state of mobile devices and the user's immediate environment are the bedrock of mobile contextual information and the most common starting points for building contextually aware services.

Device sensors

Today's smartphones already contain multiple sensors that generate various types of device and environmental data. Standard components typically include two cameras front and back; two or more microphones; an accelerometer to measure acceleration; a gyroscope to measure orientation; a magnetometer (compass); an ambient light sensor and a proximity sensor.

The purpose of sensors is to create an accurate, robust depiction of the position of a mobile user in physical space through his device, time-of-day and how that relates to his current calendar or situation; and his proximity to other devices, services, objects or locations. Applications can access and mine this data to adjust automatically or return information or suggestions based on where the user is and what he is doing.

This is fueling an innovative push by mobile technology OEMs to launch a new class of processors dedicated to capturing and packaging sensor data. The Motorola X8 Mobile Computing System and the Apple M7 are two early examples.

The Motorola X8 Mobile Computing System includes a contextual processor and a natural language processor in addition to its main CPU. To save battery power, the X8's contextual processor might work with a device accelerometer, gyroscope and ambient light sensor to detect whether a mobile device is in the user's pocket, in a bag or lying face down. The main processor uses that data to light up the display only when the user needs it. The contextual processor also feeds into more dynamic situations, like when a user is trying to take an action shot with the camera. It uses accelerometer data to detect motion, checks ambient light and proximity sensors to determine if the phone is out of the user's pocket that suggests the user is ready to shoot.

The Apple M7 is a separate processor (or coprocessor) announced as part of the iPhone 5S launch. Like the Motorola contextual processor, the M7 builds a sophisticated motion model of the user without requiring resources from the device's main processor. Along with saving battery life, the M7 enables developers to pull motion sensor data into their applications through its CoreMotion API[1].

Power management is just one example of the new generation of motion sensor-focused processors. Another important function is indoor navigation. Whilst communications infrastructure and services providers continue to build out network coverage indoors (more about this in the next article), motion technology providers are using device sensor information to derive more accurate indoor directions for users.

Regardless of its ultimate purpose, sensor data must be normalised and packaged if it is to be used by higher-level applications like fitness or indoor navigation. A big part of this involves filtering out environmental noise. For example, the compass (magnetometer) in a mobile device contends with magnetic anomalies when a person enters an elevator or rides an escalator. These activities slightly change how the mobile device interprets magnetic north.

There is a growing cadre of start-ups and established chip vendors fielding hardware and software solutions for improving the accuracy of sensor data by filtering environmental noise and combining multiple sensor inputs for contextually richer and more meaningful data for use by applications. [See Figure 2]

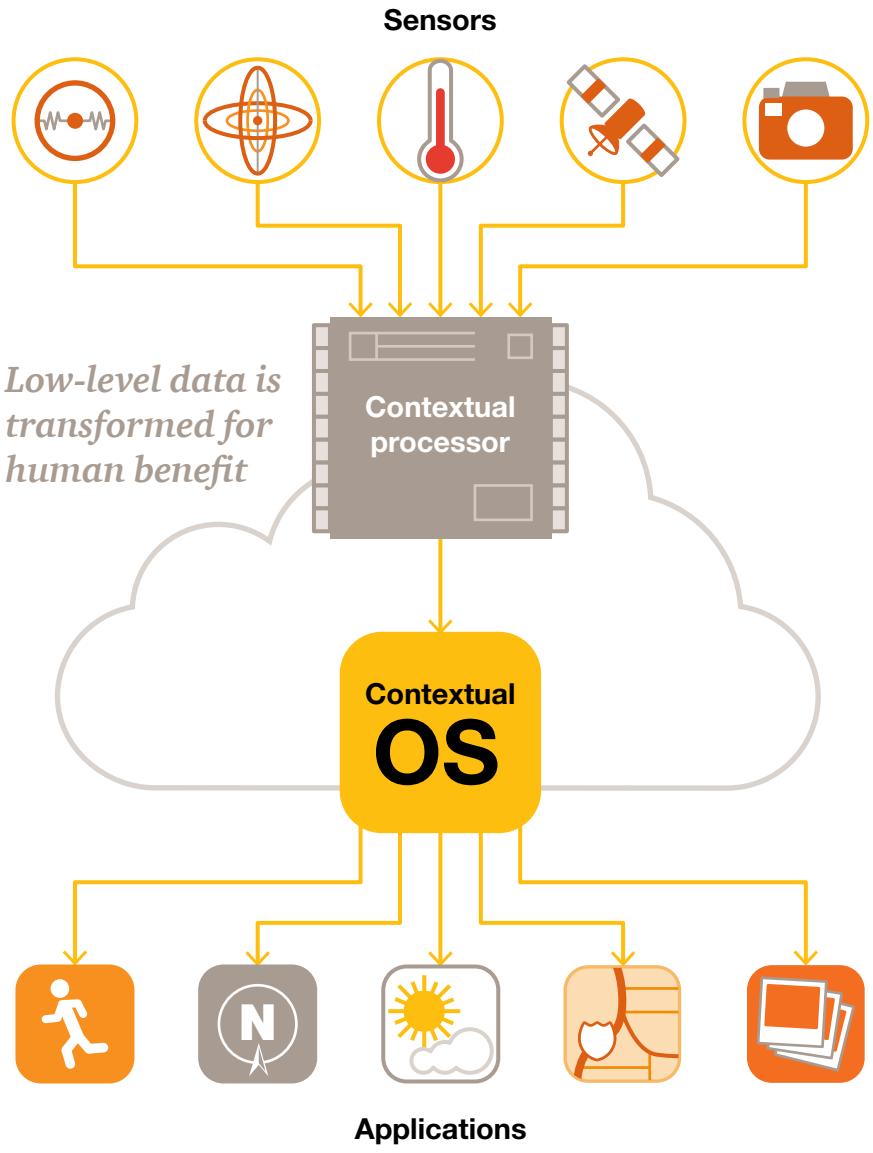
1 For more information go to https://developer.apple.com/library/ios/documentation/CoreMotion/Reference/CoreMotion_Reference/_index.html

The capability to turn raw sensor data into something usable by applications is called sensor fusion. Sensor fusion is device-resident software that combines sensor data or data derived from disparate sensor sources to produce information that is better in some way than is possible with individual sensor sources alone. Better might mean more accurate, more complete and more dependable, or an emergent view generated by fusing the results of several distinct sources of sensor input. Optics offers an early example; specifically, stereoscopic vision, in which a computer calculates depth information by combining 2D images from two cameras set at slightly different viewpoints.

Dan Brown, CEO of Sensor Platforms, a venture-backed company in Silicon Valley, says the goal of sensor fusion is to create a 'confidence engine' that aggregates, normalises and packages sensor data into a form usable at the application layer. "Let's say we detect movement of the device," he says. "Is there movement because the user stood up, or because the user moved the phone from one side to the other of his jacket? Or did he pick up the device from a table? Sensor context awareness identifies those movements and the confidence engine sends that information up to the application. The application is only responding to the information that we are giving it, and we're not bombarding and waking up the application processor each time there's an update."

Enabling better system performance whilst making situational data available and useful for applications incentivises OEMs to pack more sensors into almost every networked device with the smartphone acting as the primary sensor hub. The other side of the coin involves instrumenting the outside environment with sensors, tags, beacons and other targets that will interact with mobile devices to make a sensor-derived personal cloud of information and services closer to reality.

Figure 2: From input to action



The outside world becomes the desktop

Sensors are not restricted to mobile devices. The diffusion of sensors and proximity technologies into physical locations and objects is equally rapid. Service providers are instrumenting public environments, ranging from sports stadiums to shopping malls, with sensors, beacons, tags and other radio-connected computing nodes. The goal is to enable the user to share information with her proximate environment and get something in return.

An example is a coffee shop that recognises a regular customer when she's within 10 metres of the front door based on the ID signature of her smartphone or fitness tracker. Armed with that knowledge, the coffee shop might pre-order the customer's favourite beverage.

A key capability for making the outside world responsive in this way involves creating peer-to-peer (P2P) connections between sensor-equipped mobile devices and physical venues or objects. A significant effort involves the use of physical proximity 'beacons' that are embedded in physical locations to connect P2P to mobile devices to trigger a processing event. [See sidebar, Beacons and ID, below]

Along with physical beacons, the core networking technologies, such as Wi-Fi and Bluetooth, are already widespread, with newer technologies such as LTE Direct on the way. However, data transmission is only one part of a larger palette of capabilities required to remove friction in P2P networking. Developers trying to build applications must contend with device and service discoverability, security, different radios or platforms, pairing protocols and the like to make *ad hoc* device and service connections easily accessible to the end user.

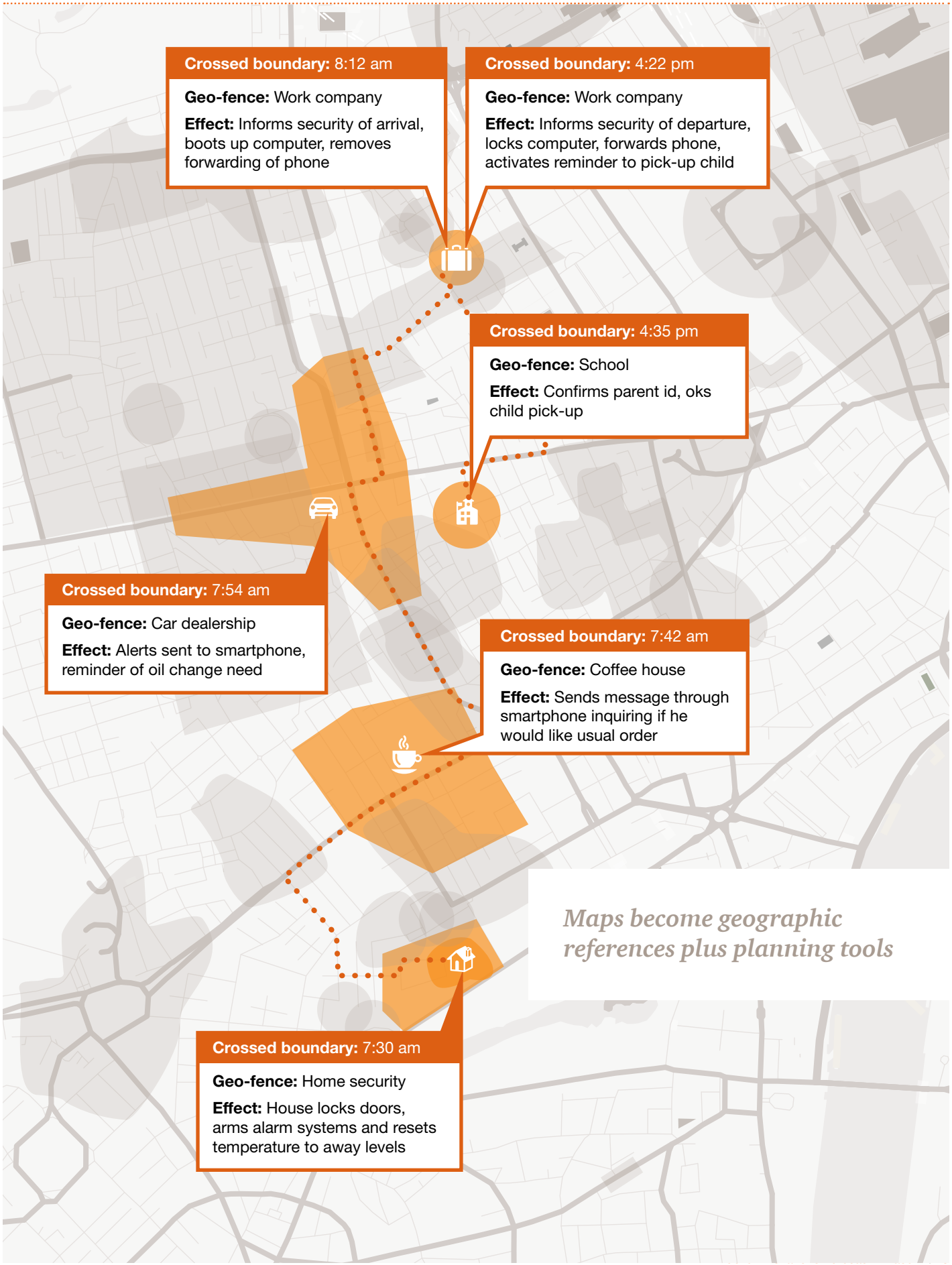
Beacons and ID

A significant problem with indoor navigation is the line-of-sight requirement for most GPS technologies, which often proves difficult inside shopping malls and other buildings. At the same time, new indoor navigation efforts using low-power radio beacons within buildings are gaining scale. Beacons are small, wireless sensors that are placed within a physical space and transmit an ID code to announce their presence to a compatible mobile device and, in so doing, establish a digital perimeter.

A user's mobile app can be enabled to look for a beacon's ID transmission and use that information for better navigation to a target area in an indoor space and for triggering a notification of location-relevant content, offers and promotions. Qualcomm introduced Gimbal proximity beacons in 2013 to complement GPS by allowing devices and applications to derive their proximity to beacons that continually broadcast an ID code twice a second. In September 2013, Apple announced its iBeacon indoor positioning system. Like Qualcomm, iBeacons are low-power, low-cost transmitters located within an indoor structure. When an iOS7 or Android user enters the transmission perimeter established by an iBeacon, push notifications can be sent to the device whilst the physical location can track entry and exit data generated by users interacting with the beacon.

The Qualcomm and Apple beacons employ Bluetooth Smart, also known as Bluetooth Low Energy, to enable their systems. In contrast to Near Field Communication (NFC), which requires that a compatible device and target be within 20 centimetres of each other to trigger an event, Bluetooth Low Energy can reach up to 50 metres in distance. It is still too early to determine whether NFC or Bluetooth Low Energy will prevail in the battle to navigate the great indoors. ■

Figure 3: **Macro-map and micro-tasks**



Maps become geographic references plus planning tools

Amongst evolving new capabilities are some of the first frameworks for handling the higher-level challenges of P2P networking. AllJoyn is an open-source project launched by Qualcomm that provides a universal software framework and core set of system services to enable interoperability amongst connected products and software applications to create dynamic proximal networks. Its core building blocks and services address discovery, connectivity, security and management of *ad hoc* proximal networks amongst devices that can interact regardless of how they are connected—Wi-Fi, Ethernet, Powerline, etc.

Personal cloud

Proximity technologies like AllJoyn, which fit on top of established networking protocols like Wi-Fi Direct (used by Apple AirDrop) or Bluetooth, aim to create a new kind of cloud—a personal cloud of devices and applications around the user wherever he goes. It's a dynamic environment that evolves as the user moves through the physical world. Most likely managed by a smartphone, a constellation of mobile devices owned by the user will tap into that proximal cloud to access information and services.

Dr. Paul Jacobs, the CEO of Qualcomm, refers to this personal cloud and the capabilities it unleashes as a 'digital sixth sense' because it uses all the sensor data as interpreted and extended by analytics to augment the human's five senses.

Whilst proximate capabilities like AllJoyn make *ad hoc* networking possible for devices, other new capabilities like geo-fencing aim to draw dynamic, virtual perimeters around physical locations of any size, from office buildings to entire neighborhoods. A geo-fence is a digitally created border around a geographic point. When a location-aware device enters or exits a geo-fence, the device receives a notification. Originally designed for child location services, geo-fencing leverages awareness of a user's current location with awareness of nearby features that may be of interest based on a user's stated preferences or inferred from her past history.

To create a geo-fence, a service provider specifies latitude/longitude of the target location and then specifies a radius from that point to adjust a proximity filter that will determine whether a user receives a notification. A geo-fence can be dynamically generated—as in a radius around a store or point location. Or a geo-fence can be a predefined set of boundaries, like school attendance zones. Service providers can have multiple active geo-fences and even nest them within each other. They can also specify an expiration time and date for the geo-fence.

On either side of a geo-fence, a user or a venue owner can employ identity beacons that trigger an action when a border is crossed. Some of these beacons are actual physical devices, such as Qualcomm's small blue keychain beacon, a simple device that uses Bluetooth Low Energy (BLE) to send out an ID signal twice a second. A contextual application running in the background on a mobile phone or another device will send the received token ID to a server, which can send information back to the phone. The specific information payload depends on the application and the behaviour to which it responds.

Some of the first trials of identity beacons and contextual services have already been run in sports venues such as AT&T Stadium, home of the NFL's Dallas Cowboys. Other public spaces, such as conference arenas, are experimenting with ID beacons to determine where and for how long people visit specific geo-targeted areas such as concession stands or parking garages.

Geo-fencing is expected to expand beyond just navigation and alerts to include more direct transaction activity. This is because most 'real' commerce still does not take place online, according to Jeff Miles, VP of Mobile Transactions at NXP, a semiconductor company. "The number is still less than 10 percent of the total transactions are what we would call pure online transactions, think of payment transactions," he says. "That means a full 90 percent still happen at a physical point of sale. So the ability now to interact with those touch points with an electronic device, that's a huge opportunity of how you can affect those transactions."

The spread of geo-fences, beacons, Near Field Communication tags and other sensor-based devices and services is really about connecting the power of

the mobile device and the cloud with physical places and objects. Some call it the Internet of Things or even more grandly, the Internet of Everything. Regardless of word choice, in short order nearly each and every connected device or location will become a networked computing node, a development with staggering implications for the mobile technology and services ecosystems.

Conclusion: Signal or noise?

We want two things from any contextual model. The first thing we want is a filter. We want technology and services to remove everything, except the information that we *really* need to accomplish our objective. We want to find our way outside or indoors. We want to know how many steps we took or calories we burned. But we don't want a dead battery by the middle of the day. We don't want to miss an important call because of a game or a retail offer.

Sensors and intelligent processing of our immediate physical situation help filter out as much background noise as possible. Understanding our physical context is also important for maintaining the performance of devices. But that's only half of the equation.

After we filter out the noise, we want to make sense of the signal. We want to apply intelligence to the filtered information that is important to us. Getting to that point requires that we build on top of our physical context to include stored information, preferences, applications and services in the network and in the cloud.

Granted that today's mobile technologists have a good idea for making that happen, there remain larger unsolved problems around capturing physical context and making it valuable for the end user. Some of these problems are technical, such as incorporating machine vision into the portfolio of sensors capturing contextual data or determining the optimal standards for peer-to-peer communication between sensor-equipped mobile devices and objects and locations.

However, the more important innovations will be social and business related. For example, how should service providers alert and engage users with a geo-fence smoothly and quickly? Of course, there are technical details for making that connection, but the process starts by convincing the end user of the value. Moreover, the notion of privacy in a contextual age is no longer a binary decision, but comes in degrees and layers. Creating the interfaces that allow end users to adjust their privacy settings as easily as they change the volume on their devices or search key words is still a work-in-progress.

The next few years will bring the merging of physical space and digital information/services into sharper focus. As we make our mobile devices and our physical environments more intelligent, our basic definition of interactivity must expand to include how people access and manipulate digitally enabled locations and objects, not just web pages. The irony, of course, is that linking the physical world to the digital world to expand interactivity requires a transformation of telecommunications as profound as that unleashed by the original Internet. Networks and the end user's virtual context will be the focus of the next article in this series. Stay tuned.

Let's talk

If you have any questions about the Mobile Innovations Forecast or would like to discuss any of these topics further, please reach out to us.

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