IT@Intel White Paper

Intel IT
Context-Aware Computing
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Creating Business Value through Context-Aware Computing

Context-aware computing provides task-relevant information or services, making tasks more efficient and improving decision making through context-driven recommendations.

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Executive Overview

Intel IT is discovering that context-aware computing offers substantial business value across the enterprise. Context-aware computing factors in the situation of an entity—whether a person, place, or thing—and provides task-relevant information or services, making tasks more efficient and improving decision making through context-driven recommendations.

Examples of broad enterprise use cases that offer business value include the following:

- **Employee and team productivity.** Context can improve team effectiveness and the use of office resources while personalizing computing interfaces.
- **Enforcement of IT consumerization, security, and privacy controls.** Context can be used to enable a flexible and dynamic security model that can adapt to a user's work or personal situation, enforcing the appropriate controls to protect corporate intellectual property and assets, and to protect a user's personal information.
- **Business continuity.** Sensors can monitor factory equipment to help predict equipment failures and enable proactive maintenance.
- **Facilities management.** Sensors can help reduce energy costs by providing better energy management and can help reduce the need for preventive maintenance through automation.

We are just beginning to use context awareness at Intel. We are developing a central context-aware computing service because many use cases have certain aspects in common. This centralized context as a service transforms available sensor data into information that can be used and reused in multiple use cases to create business value. A centralized context-awareness service also helps future-proof our investment in context-aware computing against inevitable changes in sensors and data types.

We are working to realize the business value of enterprise-level context computing and have already conducted several successful proofs of concept. We plan to continue to evaluate sensors, share learnings with Intel product groups to improve sensor accuracy, and manage privacy risks.

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ESTABLISHING CONTEXT-AWARE COMPUTING USE CASES FOR THE ENTERPRISE

In the consumer market, context-aware applications are fairly common. However, in the enterprise, context-aware applications are currently rare because of their technical challenges, security risks, and privacy concerns. That reality is changing. As connectivity, mobility, and sensor technologies continue to evolve, they create new opportunity in the enterprise. We can now digitally gather the context in the form of information that can be used to characterize the situation of an entity—whether a person, place, or thing—and use that information to provide business value.

We are developing context-aware computing because we believe it has the potential to provide significant benefits that can empower end users and the enterprise as a whole. For example, context-aware computing can provide task-relevant information or services, automate or make tasks more efficient, and improve decision making through context-driven recommendations. We foresee diverse uses for context data in the enterprise that include the following:

- Employee and team productivity
  - Improve team collaboration and project velocity by providing a way for employees to share information—if they choose to—about their current context, such as whether they are in or out of the office.
  - Improve the use of office resources such as conference rooms, printers, and available desks or parking spaces.
  - Provide personalized just-in-time information, such as the time and location of an employee's next meeting. If the meeting is at a different campus, the information could include directions to vacant parking spaces closest to the meeting location.
  - Personalize computing interfaces; for example, an application might know what resources are nearby, such as printers, scanners, and networks, and automatically connect to them without any effort on the employee's part.
  - Increase processing power by taking advantage of unused CPU cycles on workstations distributed across Intel's private enterprise cloud.
- Enforcement of IT consumerization, security, and privacy controls
  - Enable IT consumerization by supporting a flexible and dynamic compute model that adapts to a user's work or personal situation.
  - Support a dynamic security model to protect corporate intellectual property and assets.
  - Protect corporate physical assets, such as laptops or printers, by using sensors and geofencing.[1]
  - Manage access to an employee's personal information based on his or her consent; for example, an employee may choose to share his or her specific geolocation information with other co-workers.
- Business continuity
  - Monitor equipment, such as factory water pumps and fans, to help predict equipment failures.
  - Combine equipment monitoring data with key operating parameters to create dashboards and alerts for equipment health.
  - Enable proactive maintenance that would reduce downtime and potential damage, as well as reduce overall maintenance costs by enabling an "as needed" rather than a "just in case" preventative maintenance model.

[1] Geofencing is the process of establishing location-based borders using positioning technology.

- Facilities management
  - Reduce energy costs by providing better energy management.
  - Improve data center load balancing by optimizing server workload based on power, temperature, and workload priority.
  - Automate equipment monitoring so facility technicians do not have to perform preventive checks; they can work on projects with higher business value.
  - Provide space-usage data that can help planners optimize new or existing office areas based on actual usage. This data could help match workspace supply with demand and forecast future needs.

EXPLORING CONTEXT-AWARE COMPUTING AT INTEL

The development of context-aware computing is part of Intel IT's larger effort to enable enterprise applications to support the devices of today, such as touch-enabled business Ultrabook™ devices and tablets, and also develop applications that are ready for emerging interaction methods, such as voice, gesture, and perceptual computing.

As Figure 1 illustrates, we are just beginning to make use of context data at Intel. The Internet of Things—new sensors, new entities, and new ways of creating, gathering, and using information without requiring data entry by humans—is constantly expanding, making more and more context data available. By developing a centralized approach to context-aware computing, we can future-proof our context investment against inevitable changes in sensors and data types. At the same time, we can implement governance and accountability processes and enforce privacy and security controls that can adapt to new technologies and use cases.

Intel IT, in partnership with Intel business groups, is investigating context-aware computing in the enterprise through three activities.

- **Sensor evaluation.** Many types of environment sensors currently exist, and more are entering the market. The goal of our evaluations is to identify the types and combinations of sensors that provide the best information and, therefore, the most business value.
- **Delivery of context as a service.** As we develop a central solution, we focus on four areas.
  - Abstraction that hides the underlying complexity from users and application developers
  - Aggregation to combine context data from multiple sources
  - Interpretation of sensor data to transform raw data into meaningful context
  - Policy management to enforce privacy, security, and legal controls
- **Proofs of concept (PoCs).** Projects can demonstrate enterprise relevance and business value while generating ideas for more use cases.

Increasingly, Intel and OEMs are adding sensors to platforms. We are deploying to Intel employees the newest generation of business Ultrabook devices, which are equipped with various sensors such as indoor location sensors. We will soon be deploying Intel® architecture-based smartphones and tablets that also include sensors. In addition to the high-value platform-based sensors, we also believe that discrete sensors—sensors that are independent of a compute platform, such as room-occupancy sensors—can add value to the computing experience. Our context-awareness service presents an opportunity to use client and environment sensors to deliver substantial value across the enterprise.

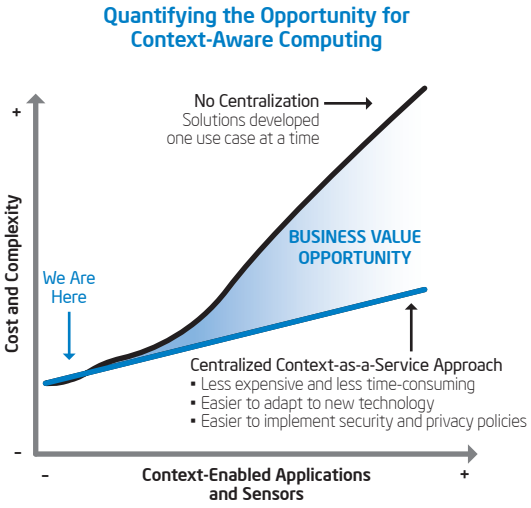

Figure 1. Having identified diverse enterprise use cases for context-aware computing, Intel IT believes it is more efficient to establish a centralized approach instead of creating a unique solution for each use case.

Sensor Evaluation

Sensors can provide context for the following types of entities:

- **Person.** Examples include employee, customer, supplier, and visitor.
- **Place.** Examples include conference room, café, restroom, and parking lot space.
- **Thing.** Examples include client device, server device, factory water pump, printer, vending machine, and lab equipment.

In addition to categorizing sensors as either client or environment, sensors can be either hard or soft.

- Hard sensors are either discrete or integrated. Examples of discrete hard sensors include motion sensors, badge readers, radio-frequency identification scanners, location sensors, and climate sensors, such as temperature, humidity, and atmospheric pressure. Business Ultrabook devices, tablets, and smartphones are often equipped with integrated hard sensors, such as location awareness, accelerometers, compasses, and gyroscopes.
- Soft sensors use applications to create context. Examples include appointment and shift calendars, conference room booking tools, user preferences, and applications that provide load balancing for network activity.

INTEGRATING AN ECOSYSTEM OF SENSORS WITH THE BUSINESS

We already have both hard and soft sensors deployed at Intel. For example, our employee badge reader is a hard sensor, and user presence in our instant messaging system is a soft sensor. As shown in Figure 2, our experience has shown that business value increases exponentially when combining sensors of any kind, and combined sensors provide more useful information than single sensors alone. In many cases, this value can be achieved by business applications without installing new sensors. For example, application developers can simply use data from existing hard and soft sensors, such as collaboration and messaging tools and the badge reader.

To achieve an integrated ecosystem of sensors, we must surmount some technical challenges associated with sensors installed in the enterprise environment. For example:

- **Sensor power.** Decisions about powering sensors (particularly discrete hard sensors) impact both initial installation costs and long-term sensor support costs. Hard-wired AC or DC power can increase initial installation costs but can reduce sustaining costs and improve reliability. Battery power reduces installation costs but requires recurring battery replacement costs (primarily labor) over the long term and can reduce sensor reliability.
- **Sensor connectivity.** To provide data to cloud-based applications, sensors must be connected to a network. Similar to power choices, connectivity choices have advantages and disadvantages. Wireless connectivity can be quick and inexpensive to install but may introduce security and wireless channel interference challenges. There are also trade-offs between standard IP-based LAN/WAN connections compared to a low-power mesh network that is either standards-based or proprietary.
- **Sensor trust.** As the mission criticality of context-enabled enterprise applications increases, so will the importance of establishing a trust model for sensors that provide context data. A standards-based mechanism for validating the identity and authenticity of sensors and preventing sensor-injected malware will become increasingly important.
- **Data collection methods and protocol.** Ideally, all sensors would use the same standardized communications protocol and would support both query/response (synchronous) and publish/subscribe (asynchronous) data collection methods. However, at this exploratory stage, we are evaluating and testing hard and soft sensors that use various sensor protocols and data collection methods. Unifying these differences and masking complexity is one of the key capabilities of the

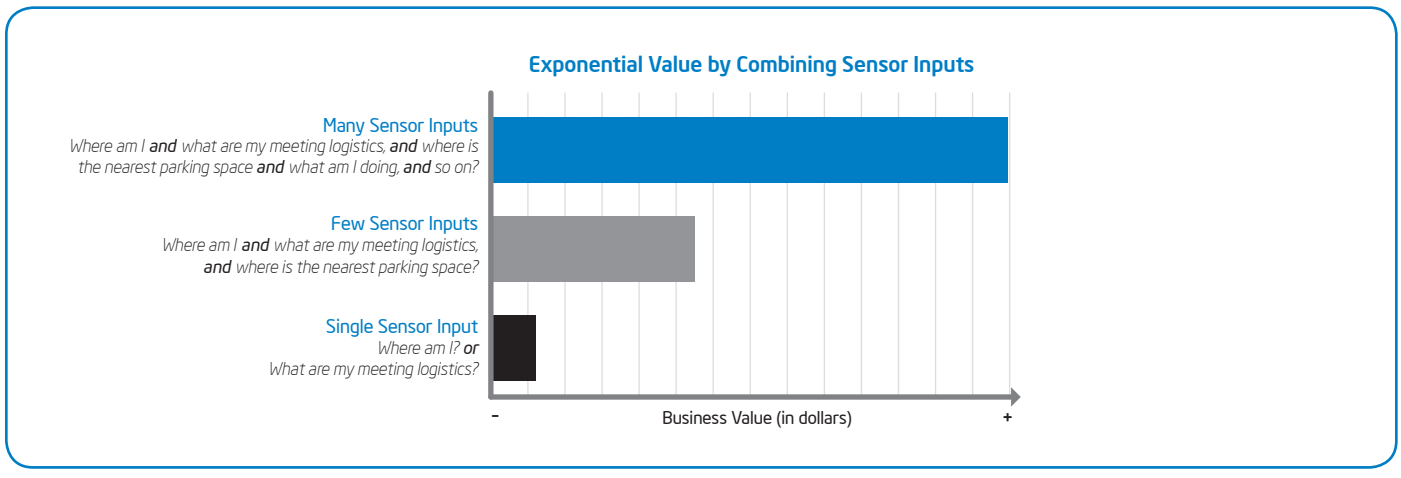

Figure 2. The layers of information produced by a combination of sensors provide the best business value.

context-awareness service we are building (see "Delivery of Context as a Service").

- **Privacy governance and accountability.** Intel collects personal information for specific purposes, and employees are notified of that purpose when they provide information. Processing information for a different purpose or to aggregate it with other data may require additional notification and consent. As we develop context-aware solutions, we must be able to determine which sensor data represents personal information, how an employee has consented to have that information used, and at what point sensor data transitions from being general and anonymous to personal and identifiable.

We are discovering the business advantage of creating applications that connect with a variety of hard and soft sensors. An ecosystem of sensors throughout the enterprise will enable use of these sensors and support the ability to customize the ever-expanding Internet of Things for specific business usages.

ENTERPRISE REQUIREMENTS

In addition to costs, such as those related to acquisition, installation, and maintenance, we use the following criteria when evaluating sensors for use at Intel:

- **Accuracy.** Many enterprise use cases demand a level of sensor data accuracy that is much higher than similar consumer use cases. One example is location sensing for improved collaboration and meeting effectiveness. Determining whether an employee is inside a specific room or within a nearby corridor requires a level of location precision that is not necessary for outdoor navigation systems based on the Global Positioning System (GPS). Likewise, when the enterprise uses context data to dynamically adjust the level of security protection applied to a user's computing environment, the system must be able to trust that the sensors are providing accurate data that is not subject to impersonation or spoofing.
- **Flexibility and agility.** Sensor technology is changing rapidly, and some of these changes are unpredictable. Intel IT needs an approach to using sensors that allows us to use the best available sensors today, with the flexibility to deploy new sensors as they become available. If adoption of new sensor technology requires reworking or rewriting existing context-enabled business applications, context adoption will be severely limited.
- **Ability to integrate sensor data.** While simple context-enabled capabilities can be delivered using a single sensor, the value of the capability is often greater when data from multiple sensors can be combined. This approach will involve combining data from integrated and discrete sensors and applying business rules to the raw data to transform it into useful context data.
- **Privacy.** The ability to provide context awareness to applications raises concerns about security and privacy. We are using Intel's established privacy principles to ensure that our context as a service is designed with privacy in mind. It is important to define and implement policies to manage and protect personal information throughout its entire lifecycle. As we move forward with context-aware computing at Intel, we will continue to evaluate the privacy implications of new sensors and use cases to ensure that appropriate privacy controls are in place.

Delivery of Context as a Service

There is value in sharing, reusing, and aggregating context data across multiple use cases. Therefore, we believe it is more efficient, in terms of both development time and expenditure, to establish a central context-aware computing service instead of creating a unique solution for each use case. Intel IT is developing a centralized context-awareness service that transforms sensor data into information that can be used and reused to deliver business value. As part of our efforts, we are designing a solution with privacy controls in place throughout the data lifecycle

Implementing Context Awareness That Enables Personal Privacy

Security and privacy are critical concerns when considering context-aware computing. We are applying Intel's privacy principles early in the design cycle to ensure that context as a service is designed to enable privacy from the beginning. We are educating the development team on privacy principles prior to design so that all parties understand, respect, and follow Intel's privacy policies. Developers need to know what data is considered personal so it can be handled appropriately throughout its lifecycle. They must also clearly communicate with application users about what data is being collected and why, and provide users with control over how their data will be used.

As more sensors begin to be used and more applications begin to use context data, developers must factor privacy considerations into the design. For example, in our room occupancy use case we selected sensors that did not collect personal information. The selected sensors only measure sound levels to help determine occupancy; they do not record sounds and are unable to determine how many people may be in a room. The context-awareness service shares only whether the room is occupied. In use cases where personal data is necessary, the appropriate controls must be in place to provide information only to applications where the employee has given prior consent.

Our goal is to centralize security and privacy controls so developers can focus on delivering unique business value through their applications' functionality, user interface, and business logic.

(see the sidebar "Implementing Context Awareness That Enables Personal Privacy").

Context as a service provides an abstracted set of data services—sensor abstraction, sensor aggregation, data interpretation, and policy enforcement—that insulates applications from rapid technology change and provides context data as a shareable and reusable resource. For example, Intel IT's Wayfinder[2] application helps employees navigate from their current location to a desired point of interest, such as a printer, cafeteria, or conference room. This application uses the same context sources as the Conference Room Occupancy PoC (described in detail in "Proofs of Concept"). Context as a service enables both of these applications, as well as applications developed subsequently, to access the context data they need without having to re-create infrastructure and business logic.

As shown in Figure 3, the context-awareness service acts as middleware between the raw data from the sensors and the business applications that consume that data. The context-awareness service includes business logic that abstracts, aggregates, and interprets the data. The business logic also enforces corporate security and privacy controls.

SENSOR ABSTRACTION

While sensor technology is likely to change rapidly and often, the middleware tier helps provide application developers and end users with a consistent interface that does not need to change frequently. This stable interface of context data can accommodate adding new or modified sensors as they become available, but business applications won't need to be changed or rewritten each time a sensor changes.

SENSOR AGGREGATION

Often, more than one sensor is needed to answer a context question accurately. For example, a single motion sensor could determine conference room occupancy. However, obtaining accurate results requires sufficient movement in the room to indicate occupancy. Context as a service can combine sensor data from multiple sensors, such as motion, light levels, and sound levels, thereby providing a much more complete and accurate set of data.

DATA INTERPRETATION

Raw sensor data is often not useful to business applications, because it needs to be interpreted after it is aggregated. Context as a service provides basic interpretation of sensor data, especially in cases where a common interpretation of sensor data is highly desirable. For example, the service could transform aggregated raw data from a motion sensor, a light-level sensor, and a sound-level sensor into "Occupied" or "Vacant." Providing this functionality in the context-awareness service does not preclude business-specific interpretation where needed; business applications can receive the raw sensor data for custom interpretation in most cases.

POLICY ENFORCEMENT

The context-awareness service provides foundational security and privacy controls that enable users to regulate how their context data can be used in applications and under what circumstances. The service also provides employees with the ability to revoke access when necessary. In some cases it would be against policy to allow access to raw sensor data; however, access could be allowed for an interpretation of that data.

Beyond these fundamental controls, business applications typically need to provide additional business-specific security and privacy controls that are required for the business problem being solved. For more information on how Intel IT implements privacy controls for context as a service, refer to the sidebar "Implementing Context Awareness That Enables Personal Privacy".

Proofs of Concept

We conducted several PoCs and technology evaluations related to context-aware computing in the enterprise. These PoCs help us understand the capabilities of a broad range of discrete and integrated sensors, identify enterprise usages, and understand privacy implications so we can design appropriate privacy controls. They also demonstrate the business value of context-aware computing and have inspired us to learn more about what can be accomplished using context. This section provides details about three of these PoCs: conference room occupancy, the Wayfinder application, and intelligent camera disablement.

[2] See "Getting a Headstart on Location-based Services in the Enterprise," January 2013.

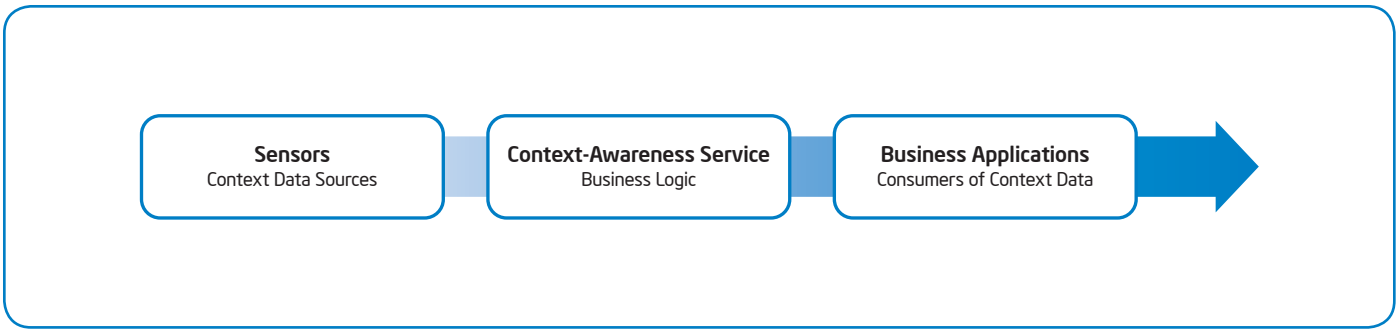

Figure 3. Our three-tier model enables business applications to access context data without re-creating infrastructure and business logic.

CONFERENCE ROOM OCCUPANCY

Conference rooms are in high demand at Intel. While we have an online system for booking conference rooms, we were unable to tell from looking at the schedule whether a room was physically occupied. We developed a solution that displays room status on a digital sign (see Figure 4), using both room schedule information from Intel's Conference Room Scheduling tool and room occupancy information from sensors installed in the rooms. The sensor data is consumed, interpreted, and published using context as a service.

PoC Description

For this PoC the occupancy information was displayed at three interactive digital signage locations. Context as a service also allowed us to easily make it available to other applications, such as an indoor navigation application on smartphones or a business Ultrabook device. The 90-day PoC involved two floors in one building, covering approximately 90 conference rooms, collaboration rooms, and internal phone booths.

The digital signage indicated whether a conference room was occupied. The sensors provided motion, light, and sound levels; this data was combined by the context-awareness service to determine room occupancy. By using a sensor that collected only sound levels instead of performing complex voice processing analysis, the sensors helped protect users' privacy. The sensors are not capable of determining how many people are in a room and mitigate potential concerns about remote eavesdropping or audio recording.

Benefits Realized

In addition to the benefit of helping employees determine room availability, the PoC demonstrated an even more important business value: It gives us the ability to use context data to measure the actual use of a meeting space in order to match supply with demand and to forecast future needs. We can apply what we learned about space usage when we build or remodel Intel campuses. Also, we can extend this PoC to other use cases, such as energy management. Overall, we received positive feedback from participants in the PoC as well as strong interest from Intel business groups and external companies.

Transforming the IT Ecosystem to Support the Applications and Devices of the Future

We have identified five criteria that lead to a better end-user experience: security, ease of use, platform independence, device independence, and support for emerging devices and interactions. These same criteria create a better application developer experience by removing obstacles and providing readily available tools to increase application developer productivity and efficiency.[c]

Our context-awareness service can create reusable components that make context-aware application development easier. In addition to creating applications that work better now and can take advantage of future technology changes, our work affects almost every infrastructure component, including mobile device management, mobile application lifecycle management, and application testing and scalability.

[c] For more information about our new initiative that focuses on accelerating delivery of applications to our business partners and employees on their mobile platform(s) of choice, see "Accelerating our Path to Multi-Platform Benefits," May 2013.

Figure 4. During the Conference Room Occupancy proof of concept, room status was displayed on a digital sign.

WAYFINDER APPLICATION

Intel IT recognizes the great opportunity for using location-based services in the enterprise, and we are already piloting several location-based applications that consume these services. Employees can choose to use location-based services to help derive value from their own location and the relative location of other resources in the work environment.

PoC Description

In late 2011, we began a technology evaluation and PoC of a smartphone application that provides indoor campus maps and navigation that enables employees to locate the nearest conference room, printer, defibrillator, or exit at a particular campus. The application uses indoor Wi-Fi* trilateration[3] to show an employee's current location on the campus map and delivers indoor turn-by-turn navigation. The PoC was designed to have minimal device and configuration requirements. We are now beginning broader deployment of the Wayfinder application.

Benefits Realized

Using location-based services, such as the Wayfinder application, in the enterprise offers the following benefits:

- Employees can more efficiently connect to the resources around them and find the right resources at the time they need them.
- Employees enjoy a more seamless and continuous experience across platforms, devices, and operating systems, whether outdoors or indoors.
- Our efforts support Intel's strategic objective to develop location-based services for mobile platforms, as part of the overall compute continuum vision.

Based on the success of the Wayfinder application PoC, we conducted a subsequent Pinpoint PoC that used key learnings from both the Conference Room Occupancy and Wayfinder application PoCs. The Pinpoint PoC demonstrated the value of adding location information to other context data. In this PoC, employees connected their business Ultrabook devices to the wireless network to identify their location on campus, and then merged that information with information about a conference room's availability and occupancy information. This process provided turn-by-turn directions inside the building to an available, unoccupied conference room.

INTELLIGENT CAMERA DISABLEMENT

Intel employees' use of smartphones increases employee productivity and mobility throughout the enterprise. In particular, corporate and personally owned smartphones enable employees to access corporate data—such as email, contacts, and calendar—and other select enterprise applications, anytime, anywhere. However, because smartphone cameras pose a significant risk to Intel's intellectual property, such as sensitive manufacturing process data, we currently do not permit employees to use smartphones or personally owned cell phones in Intel's factories. We want to allow corporate-owned smartphones in our factory environment to enable new advanced mobility capabilities and productivity gains.

PoC Description

We are planning to conduct a PoC that uses context to intelligently disable smartphone cameras. Based on context, such as shift calendar, location of device, and user role, we will dynamically apply the camera-disable policy. For example, while the employee is in the clean room the camera does not function, but it does when the employee is outside of restricted areas.

Benefits Realized

This PoC will demonstrate the value of being able to dynamically control device functionality in a restricted area where business needs require a certain policy but will allow full use of device features when employees are outside that area.

Key Learnings

Based on our PoCs and technology evaluations, we believe that an ecosystem of sensors and context as a service can provide significant business value. The following list summarizes what we have learned.

- **Now is the time.** New sensor technologies, combined with ubiquitous enterprise connectivity and powerful mobile devices, make now the logical time to develop context as a service even though some components, such as certain types of sensors and middleware, are not yet mature. For example, the accuracy of certain sensors is not sufficient for widespread enterprise use. Also, the indoor location accuracy of commercially available solutions presents a challenge. We can consistently achieve accuracy within about 10 meters, although sometimes accuracy improves to 5 to 8 meters.
- **Context as a service improves the benefits of a bring-your-own-device program.** In 2008 we determined that supporting the consumerization of IT would improve enterprise security by eliminating unsecured and unmanaged use of personal devices in the enterprise. We chose to integrate employee-owned devices—including smartphones, tablets, and PCs—into our enterprise environment. When complete, our context-as-a-service infrastructure will enable us to deliver rich enterprise user experiences on devices that employees already have as well as ready-made consumer-oriented applications that can be tuned for business purposes.

[3] Trilateration is the process of determining absolute or relative locations of points by measurement of distances, using the geometry of circles, spheres, or triangles.

To achieve these goals, we must look for opportunities in the consumer application market and apply the appropriate level of security and management to all devices.

- **IT needs better access to back-end services.** The use of context-enabled enterprise applications often involves a combination of context data from a variety of hard and soft sensors as well as data from enterprise back-office systems. Further, these applications are relevant and valuable when deployed on a diverse set of client platforms ranging from managed business Ultrabook devices to employees' personal mobile devices. Therefore, it is important that we deliver future systems that are open and easily integrated, making no assumptions about any device: how it is managed, its connectivity, or the required authentication method. Open, interoperable systems will help accelerate the delivery of context value.
- **Intelligent investment decisions boost business value.** We have learned that although initial cost (financial expenditure as well as time and effort) may increase, investing in a critical mass of sensors that can be used to support a variety of business usages provides better business value than investing in just a few sensors that support only a single use case. The more sensors we have available to business applications, the more context data these applications can use to inform, recommend, and support employees and business groups.

WHAT'S NEXT FOR CONTEXT-AWARE COMPUTING AT INTEL

With the rapid expansion and advancement of context-aware technologies, we plan to continue to evaluate sensors and share learnings with Intel product groups to improve sensor accuracy and mitigate privacy risks.

We are considering the following activities:

- **Develop new PoCs and projects**
  - **Expand the conference room occupancy PoC.** Test additional sensor types and explore adding the Conference Room Scheduler application as a consumer of occupancy information. Using this information, the scheduler application could release reservations for rooms that remain unused for a certain period of time. We also intend to build a multi-platform web-based application that will deliver information about conference room occupancy, similar to the digital signs used in the Conference Room Occupancy PoC, along with a smartphone application to consume this information.
  - **Parking space occupancy project.** Develop a PoC that can provide employees with contextual information about parking spaces, such as directing employees to the closest available parking space.
  - **Factory equipment monitoring project.** Develop a PoC to monitor factory equipment to anticipate failures and optimize preventative maintenance schedules.
- **Influence and support the Virtual Assistant project roadmap.** This initiative supports context enablement, using this application platform as a showcase and test bed for the next generation of context-aware capabilities.[4]
- **Re-educate application developers.** Encourage application developers to develop applications that can consume context data as a shareable and reusable resource and train them to apply privacy principles when designing context-aware applications.
- **Develop supporting data.** Sensors are only one part of gathering and providing context. Supporting data includes campus maps, parking lot maps, map metadata, and the latitude and longitude of campus resources.
- **Take advantage of sensors external to Intel.** As context awareness matures, and as consumerization becomes the norm, sensors used outside of Intel will provide useful information. We anticipate that combining data from our own sensors with data from a greater number of sensors that already exist in the larger Internet of Things can increase the effectiveness of enterprise context-aware computing. For example, today the Intel Virtual Assistant uses the GPS to help employees locate and obtain driving directions to other Intel campuses. Other sensors external to Intel may have potential value, as well.
- **Explore the possibilities.** We see a wide range of possibilities in the future, such as wearable computing combined with context-aware sensors. Location measurements, the proximity of other devices and places, temperature, humidity, sound levels, and energy could all be combined with data visualization and data mining techniques. Doing this would help us better understand how space is used or how a facility performs and operates, or determine the busiest times in a building or whether resources are being used frequently or optimally. We could also explore advanced data anonymization techniques and additional privacy controls that can limit the ability to identify a specific individual when processing his or her data in other use cases.

[4] Virtual Assistant, formerly referred to as "Business Assistant," enables employees to obtain assistance with directions, resource location, information relevant to their context and preferences, and services when they need them, just in time and on-the-go. For more information, refer to "Enabling Emerging Enterprise Usages with Client-aware Technologies," February 2012.

CONCLUSION

The combination of new sensor technology, increasing connectivity, and powerful mobile devices has created significant opportunity to make use of context-aware computing across the enterprise. We have identified a diverse set of enterprise use cases for context-aware computing that can support business goals, such as increasing team effectiveness and resource usage, improving business continuity and facility and asset management, and providing for dynamic and flexible support for consumerization and emerging device capabilities.

We believe that it is more efficient in terms of both development time and expenditure to establish a centralized context-aware service instead of creating a unique solution for each use case. This centralized approach focuses on enabling capabilities rather than developing specific solutions, insulates applications from rapid technology change, and provides context data as a shareable and reusable resource managed with privacy controls.

We have already conducted several context-aware PoCs and are in the process of launching several more. These PoCs help us understand the capabilities of a variety of sensors, identify further enterprise usages, and continue to develop ways to protect an employee's privacy. These PoCs also demonstrate the business value of context-aware computing and help create more possibilities for using context data as a business asset in an enterprise setting.

FOR MORE INFORMATION

Visit www.intel.com/it to find white papers on related topics:

- "Digital Personal Assistant for the Enterprise"
- "Getting a Headstart on Location-based Services in the Enterprise"
- "Enabling Emerging Enterprise Usages with Client-aware Technologies"

ACRONYMS

GPS	Global Positioning System
PoC	proof of concept

For more information on Intel IT best practices, visit www.intel.com/it.