

DeltaHedron Innovation Insight is a series of reports and newsletters exploring aspects of the technological future and technological innovation, with a specific focus on the strategic business opportunities, threats, risks and impact presented by emerging technologies and the dynamics of technological change

*‘Anticipating what can happen in the future is one thing,
knowing what to do about it is quite another’*

People tracking technologies

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Executive summary

The vantage point of DeltaHedron’s reports is one of exploring the strategic business opportunities, threats, risks and impact presented by emerging technologies and technological change. This report examines a number of technologies and products to ‘track people’. One of the main aims of the report is to investigate tracking of employees in hazardous industrial settings. However, the study covers a broader spectrum of technologies and applications, including tracking and identification of people in other contexts as well as assets and animals.

- A range of products are available to track people in a number of diverse work environments, including hazardous industrial settings such as offshore oil rigs, mines, factories and ports as well as for office environments and for tracking and identifying employees who are offsite or travelling. The solutions offered typically include the tracking and identification technologies as well as software systems used for control and analysis of the information and services.
- The choice of technology for tracking and identifying employees will depend very much on the requirements of the application, as well as the nature of the work environment and the physical surroundings, external environmental factors, the degree of ruggedness required and hazardous factors which need to be accounted for.
- Many products are based on established RFID, GPS and Bluetooth technologies, as well as variations on the themes such as Near Field Communication (NFC) and iBeacons. All of these have their strengths and weaknesses, and no one technology is ideal for all applications. A number of recent publications refer to continuous enhancements of these technologies, including the extension of range and battery life as well as accuracy of location. A number of the products on the market based on the established technologies also utilise more than one technology to compensate for the strengths and weaknesses of the various technologies.
- Recent reports in the public domain refer to a number of other technologies which are also used for tracking and identification. These include radio tomographic imaging (RTI), thermal sensing and LiFi. A range of biometric technologies are used, including voice recognition, fingerprint recognition, facial

recognition and retina scans. Experimental work is being done on the use of brain waves. A number of cases have been reported where employees implanted RFID chips in their bodies.

- In addition to applications aimed at tracking employees, many products focus on other diverse segments of people such as children, the elderly, people with Alzheimer's disease and dementia, shoppers, mountain climbers and adventurers. Each of the products has a number of features which can provide benefits for the segment at which it is aimed, including 'geofencing' (where the device will send an alert if it moves out of defined geospatial region) and the ability to communicate via voice or text (including pre-programmed messages) with a base (such as a parent's smartphone).
- In addition to the technological issues, the tracking and identification of people also raise many questions and concerns pertaining to legal, ethical, moral, privacy, security as well as health and safety issues. In addition, employers thinking of using these systems will also need to be mindful of behavioural issues, such as resistance to change or privacy concerns, which may influence the successful adoption and implementation of the technology in a company.
- Many products are aimed at the tracking of assets. An interesting development is Delta Airlines' recent introduction of RFID-tagged baggage tags. It is claimed that this will significantly enhance the airline's luggage handling logistics, decrease misplaced and lost luggage and also offer customers the ability to track their own luggage via an app on their smartphones.

- There are many opportunities for the development of new solutions and products to track and identify people, animals and assets. Whilst many applications will continue to utilise established technologies (such as RFID, GPS and Bluetooth), the continuous advances and improvements to these technologies offer many opportunities. There are also a number of emerging technologies which show great potential, particularly for niche and specialised applications.
- One of the most exciting sources of opportunities will be the application of other emerging technologies such as the Internet of Things (IoT), 3D printing, drones, robotics and artificial intelligence, to tracking and identification problems. This includes applications in hazardous industrial settings. Recent **DeltaHedron Innovation Insight**¹ reports investigated developments in emerging digital health technologies and the impact of emerging technologies on the insurance industry. In both cases, to name but two examples, there are many innovations which can also be applied to the tracking and identification of people, animals and assets, leading to products and solutions with greatly enhanced benefits and abilities.

DeltaHedron Ltd is a UK-based business consulting company specialising in the management of technological innovation. We support our clients with the development and implementation of innovation strategies, and in assessing and capturing the strategic business opportunities and mitigating the risks and threats presented by emerging technologies and the dynamics of technological change.

We shall be delighted to discuss the strategic business opportunities and risks of tracking and identification technologies as well as the underpinning emerging technologies and innovation strategies to translate technological opportunities into business success.

Please contact us through our website: DeltaHedron Ltd

¹ www.deltahedron.co.uk/publications/

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This report is not intended to be a historic review or an exhaustive discussion on tracking and identification technologies and products. Instead it discusses a *selected number of relevant recent* developments which may be helpful in the assessment of strategic business opportunities, threats and risks posed by emerging technologies, innovation and technological change.

An analysis of technology-related strategic opportunities, threats and risks, also needs to account for a range of factors, including evolving markets, industry structures, regulatory environments and economic conditions. This report does not emphasize all of these, but instead focuses on technological change as a driver of innovation.

Previous editions of *DeltaHedron Innovation Insight*

- [Developments in emerging digital health technologies](#), No 1.2/17, April 2017
- [The impact of emerging technologies on the insurance industry](#), No 2/17, April 2017

1. Introduction

This report considers a number of technologies which can be used to 'track people'.

Current and recent technologies used for tracking the movements of personnel in hazardous industrial settings such as factories, mines and off-shore drilling rigs are a specific focus of this study. However, the study deliberately goes broader than the primary brief and also explores a number of related technologies used for tracking people in other contexts, as well as tracking of large and small assets and animals (including pets² and animals in the wild³); and recent technological trends in the identification of individuals. The aim is to provide a wider overview in order to inform a more encompassing discussion on opportunities, risks and insights which can be applied as inputs to design and/or procurement specifications for bespoke client requirements.

Ultimately users deploy products, which are based on one or more technologies. In addition to a brief description of relevant technologies, the report also refers to several products, as examples of how the technologies are implemented⁴ and to illustrate a number of features. The report is not intended to be a comprehensive or exhaustive survey of all available products or technologies for the tracking of people, but instead focuses on main thrusts and a number of recent developments and trends.

²<http://www.booooooom.com/2016/06/07/gps-tracking-reveals-the-daily-adventures-of-your-wandering-pet-cat/>

³ <http://www.travelandleisure.com/animals/track-yosemite-bears-with-this-new-app>

'Identification' and 'tracking'

For purposes of this report it is helpful to distinguish between 'identification' and 'tracking', particularly since some technologies are used for one and/or the other.

The term '**track**' is used in this report to refer to the action of electronically determining and logging the geospatial location (physical location – 'where is the person?') and movement trajectory of a person (or other assets). Used in the general sense, tracking does not identify the specific individual being tracked. When combined with 'identification', a specific identifiable individual is tracked.

The term '**identify**' is used in this report to refer to the action of electronically identifying a specific individual ('who is it?').

Table 1 shows the four combinations and applications of track/identify, not-track/identify, track/not-identify and not-track/not-identify.

With regard to 'tracking' it is important to distinguish between the ability to determine the exact (absolute) location (coordinates) with a certain accuracy - provided by technologies such as GPS on the one hand; and on the other the ability to determine location by establishing whether an individual is present in a 'zone' - provided by technologies such as RFID. A zone is defined as a demarcated area where a sensor (or sensors) can detect RFID tags - it may be a room or floor of a building, for example. RFID technology can identify whether a person is close to a sensor (and hence whether they are in the zone of that sensor), but not absolute position.

⁴ Please note that reference to any company or product in this report does not in any way imply an endorsement or recommendation. None of the companies mentioned in this report contributed to funding of this study.

Table 1: Matrix showing four 'Tracking/Identification' combinations

	Track	Not-Track
Identify	Establishing the location and tracking movements of specific (identifiable) individuals	<ul style="list-style-type: none"> • Payments with contactless cards and tollgates • ATM transactions • Access control • Logging in to computers or mobile devices
Not-Identify	<ul style="list-style-type: none"> • Anonymous tracking of people in crowds in public spaces (such as shopping malls) • Counting people in queues at check-out counters • Intruder alarms • Proximity switches for lights 	Not applicable in this study (based on the definitions of 'track' and 'identify' in this report)

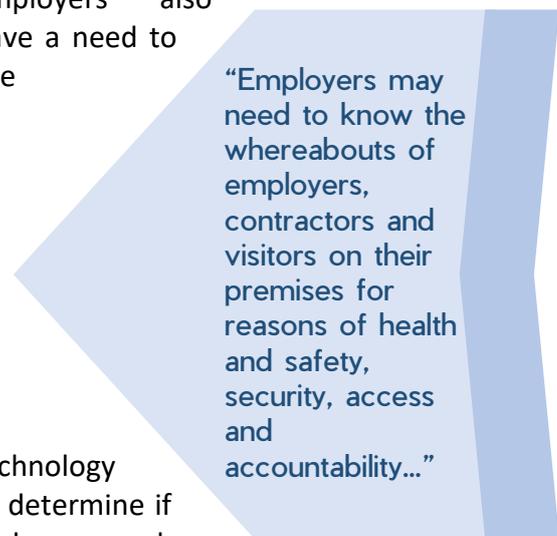
As stated above, the primary focus of this report is to explore technologies and products which address the 'track/identify' quadrant in Table 1. However, a broader perspective which considers the not-track/identify and track/not-identify quadrants for people is also useful; as is consideration of technologies and products used for tracking animals and assets. In the

context of this study, the not-track/not-identify quadrant is not applicable and hence not used.

In addition to identifying (or not) an individual and determining their location, in some applications it may be also be helpful to provide additional information about the individual, particularly biological information, such as stress levels, heart rate and so on. The sensors measuring these parameters may also be able to alert the system if the individual has had an accident, or if an explosion, fire or gas leaks were detected in the vicinity of the individual, for example.

The requirement to track people may arise from various needs, including:

- Employers may need to know the whereabouts of employees, contractors and visitors on their premises for reasons of health and safety, security, access, accountability and related reasons⁵. Some employers also have a need to use



technology to determine if and when employees have reported for work or their travel patterns. In some cases, this may be linked to verification for payment and reimbursements which are coupled to hours claimed or distances travelled. Automating tracking, identification, logging of attendance can significantly enhance efficiency.

⁵ <http://gaorfid.com/people-locating-rfid-system/>

- The presence of people may not be restricted to a specific site. Employees may be working offsite, for example at customers' premises, or may be travelling (in the case of drivers). Knowing where a vehicle is, allows for additional safety and security measures to be implemented. For example, the cargo doors of delivery trucks can be enabled remotely to open only in the geospatial location where the delivery is to be made. Additional information about the status of the driver can also be tracked in real-time, such as level of alertness and confirmation that there has not been substance abuse.
- A large conference or concert may issue attendees with tagged lanyards or wristbands which will allow them access to designated areas, and also logs which sessions were attended, which exhibits were visited, interaction patterns and so on. In the interests of privacy, some of this information can be logged anonymously.
- Parents may have a need to keep track of their children's movements to ensure their safety. Similarly, there may be a need to track the movements of elderly people living alone and people with dementia or Alzheimer's disease.

“Parents may have a need to keep track of their children's movements to ensure their safety”

- Law enforcement agencies may have a need to track criminals on the loose or on parole. In October 2016⁶ it was reported that proposals were being considered in Scotland whereby offenders could be monitored with GPS devices as an alternative to remand. The

devices could also detect their alcohol levels by measuring the amount of ethanol in sweat. Police in Canada is testing a system whereby they can fire a dart with a GPS transmitter into a suspicious vehicle, such as a car trying to evade police at high speed. The dart allows the police to track the offending vehicle without the necessity of engaging in a high-speed car chase⁷.

- Public buildings, such as shopping malls and airports need to keep track of people in the premises for various reasons. In these cases, the tracking may also be anonymous.

The following sections consider a few general systems considerations and then explore a number of technologies and examples of products used for the tracking and identification of people, animals and assets.

2. System considerations

The choice of a tracking technology for locating people will be influenced to a large extent by the application. There are a number of considerations which will play a role, including:

- Whether the requirement is for tracking, identification or both, and whether either should specifically be excluded.
- Whether the people who are to be tracked are located in a defined and demarcated area (such as a factory, oil rig, ship or university campus, for example – a zone); or whether they can roam and travel 'all over'.
- Whether the people being tracked are 'cooperative' or whether they can potentially be 'non-cooperative'. 'Cooperative' would imply that the people being tracked are aware of the tracking, agree to the activity, cooperate with the actions and contribute in a positive and proactive manner to the success of the tracking activity. 'Non-cooperative' would imply that the people

⁶

<https://www.theguardian.com/law/2016/oct/04/scotland-introduces-alcohol-tests-gps-tracking-tagged-offenders>

⁷

<http://www.vancouversun.com/delta+police+first+canada+tracking+darts+avoid+high+speed+chases/11731260/story.html>

being tracked are not necessarily contributing in a positive manner to the operation and its aims. This can range from a situation where they may not be aware that they are being tracked (such as people in a large crowd) to a situation where they are actively trying to disrupt, thwart or even sabotage the system. In the case where non-cooperative activity is foreseen, it is necessary to design specific countermeasures into the system.

It is important to distinguish between technologies, such as GPS, which determine the absolute location of the person being tracked (strictly speaking the position of the GPS receiver),

“...the difference between ‘roaming everywhere’ and located in a specific zone”

and then

requires

some form of communication to send that information back to a base station; and other technologies (such as RFID) which respond when being interrogated by a reader. In this case, position is determined by registering the location of the reader/beacon to which the RFID tag responded (since the location of the beacon/reader is known). The distinction highlights the difference between ‘roaming anywhere’ and being located in a specific zone.

In addition to providing an update on recent technological developments, this study has also revealed a number of interesting benefits, features and approaches which can be incorporated into systems for tracking and identification of people. These include:

- Motion detection is a feature which can be important in various applications, whether it be for the elderly, chronically ill or for keeping tabs on an asset.

- Factors which may influence signal strength, such as buildings, environmental conditions (including weather), water, detection range and accuracy.
- Identification issues, which can be used for a number of other functions (such as access control).
- Tracking systems for people can also incorporate biosensors, which can provide information regarding the individual’s stress levels, alertness levels, health parameters and whether they have used alcohol, for example.
- Tracking systems for people can also detect environmental conditions in the vicinity of the person being tracked, such as air quality, fire, water, explosions and the presence of gases.
- The tracking system can also be used to communicate with a base station, either through voice or text messages; and/or by automatically alerting the base station if an accident or emergency has occurred.
- A number of biometric technologies are being used to identify people, including implanted chips.

In addition to the technological considerations, there are also a number of important ‘soft’ issues pertaining to the legal situation, ethics and morality, confidentiality, privacy and data security which need to be accounted for. These include the concerns people may have and their degree of resistance and acceptance, which will influence the adoption rate and pattern as well as compliance with the tracking/identification system.

TSheets⁸ surveyed 1,000 employees in 2016 regarding their attitudes to being ‘tracked at work’. It found radical differences in opinion depending on whether they thought their employers tracked them or not. Of the employees untracked with GPS at work, only 16% had a positive opinion of this type of

⁸ <http://www.digitaltrends.com/home/smart-sensors-in-the-workplace/>

technology, while 38% held a negative opinion. On the other hand, 54% of employees tracked with GPS at work held a positive opinion, while only 5% had a negative opinion.

Recent reports discussed rules and legalities for tracking employees by GPS (albeit it in the US).^{9,10}

The French government recently approved new stricter rules for the use of drones¹¹, which will require compulsory registration of drones, mandatory installation of RFID or GSM transponders to broadcast owner details and the possibility of automatic performance-limiting devices. GSM or RFID tags would be required to transmit the owner's name, phone number, registration number and GPS location.

3. Technologies and products

This section briefly describes a number of recently reported technological thrusts for tracking (and identification), viz.

- [GPS and GLONASS](#)
- [Smartphones \(and GSM\)](#)
- [RFID](#)
- [Bluetooth](#) and [Bluetooth Low Energy \(BLE\)](#)
- [Radio Tomographic Imaging](#)
- [Thermal sensing and imaging](#)
- [LiFi](#)
- [Chip implants](#)
- [Biometric](#)
- [Sharepoint sites](#)
- [Other technologies](#)

A few specific products (and their manufacturers) are also referred to below in order to illustrate examples of the use of the technologies in specific applications.

⁹ <http://smallbusiness.chron.com/rules-gps-tracking-employees-24502.html>

¹⁰

<https://www.theatlantic.com/technology/archive/2017/01/employer-gps-tracking/512294/>

3.1 Global Positioning System (GPS) and GLONASS

3.1.1 How GPS works¹²

Global Positioning System (GPS) allows a user to determine their absolute location 'almost anywhere on the globe' in terms of coordinates. The user has a device (GPS receiver) which receives Code Division Multiple Access (CDMA) signals from 31 geosynchronous satellites orbiting the earth. The receiver will typically need to receive signals from four or more satellites at any time, from which it is then able to calculate its exact location as well as the speed at which it is travelling. GPS was originally developed in the US for military operations and was made available for public use in the 1980s.

A GPS receiver can be imbedded into dedicated navigational devices, which translate the location information and displays it on an electronic map. The devices can be standalone, or integrated into systems installed in vehicles such as cars, airplanes and ships, for example. Users can enter location information in terms of 'known entities' (such as the names of streets, buildings, hospitals and so on) or search for 'the nearest petrol station', for example – rather than having to know the coordinates of the sights. GPS can also be used to determine routes, and guide users in real-time via the routes to an indicated destination.

The GPS system will work wherever the receiver is able to detect the signals from the satellites. This can be problematic inside buildings or other areas where the signals may be shielded. Weak signals will also cause excessive drain on the device's batteries.

A standard GPS system will have a location accuracy of about 10 metres. Differential GPS (D-GPS) improves accuracy to about one metre.

¹¹ <https://arstechnica.co.uk/tech-policy/2016/09/drones-rfid-gsm-tags-owner-details-french-committee-rules/>

¹²

https://en.wikipedia.org/wiki/Global_Positioning_System

The additional accuracy is obtained by also using a network of fixed ground-based reference stations.

Location accuracy of one metre is, however, not adequate to support emerging technologies like autonomous vehicles, precision farming and related applications. Driverless cars need to be able to know which lane a car is in as well as where it is in that lane, for example.

Centrimetric GPS accuracy

It was reported In February 2016 that researchers at the University of California Riverside have developed a computationally efficient way to process GPS data, enhancing location accuracy to a few centimetres^{13,14}. The approach uses very efficient computational algorithms, enabling real-time applications.

3.1.2 GLONASS¹⁵

Globalnaya Navigazionnaya Sputnikovaya Sistema (GLONASS) or Global Navigation Satellite is the Russian version of GPS. GLONASS uses 24+ geosynchronous satellites transmitting Frequency Domain Multiple Access (FDMA) signals. It is reported that there are no clear advantages of using GLONASS, although it apparently has better coverage in northern latitudes.

An advantage can be gained, however, by using receivers which have the capability to detect both GPS and GLONASS signals, hence having access to more than 55 satellites. Many smartphones and other navigational devices now support both GPS and GLONASS. A number of mapping apps, including Google Maps, Apple Maps and Nokia HERE maps also have the ability to connect to both GPS and GLONASS.

¹³ <https://ucrtoday.ucr.edu/34932>

¹⁴ <https://futurism.com/gps-tracking-centimeter/>

¹⁵ <https://beebom.com/what-is-glonass-and-how-it-is-different-from-gps/>

¹⁶ <http://www.toptenreviews.com/electronics/gps/best-gps-trackers/>

Assisted GLONASS (A-GLONASS) uses cellular towers, which it is claimed brings additional advantages for mobile phones, including turn-by-turn navigation and real-time traffic information.

3.1.3 GPS (and GLONASS) trackers

In order to use GPS technology in a tracker, it is necessary for the tracker device to be able to transmit location information ('where it is') back to another location ('the base station') where the tracking is done and monitored. This differs from a device whose primary purpose is navigation support, where location information needs to be displayed locally on the device.

In order to be able to transmit information, the tracker needs to have the ability to connect via a [GSM](#) or other cellular network and hence incorporate a cellular transmitter (and/or WiFi and [Bluetooth](#) abilities).

3.1.4 Examples of GPS products

A number of GPS trackers are discussed below, with the aim of describing how the technology is implemented in a range of products for various applications. It needs to be stressed again that the list is not exhaustive by any means, and no endorsement of any product is intended or implied.

A survey of 'the best GPS trackers in 2017' published by *Top Ten Reviews*¹⁶ in the US compares a number of GPS trackers on a number of features, including overall rating, tracking availability, design, monitoring as well as support and costs. The application was mainly for tracking the whereabouts of children, senior citizens and pets as well as vehicles. Based on the criteria specified, the top three recommendations were Amber Alert¹⁷ (discussed below), Brickhouse Security¹⁸ and

¹⁷

http://www.amberalertgps.com/?utm_source=shareasale&utm_medium=banner&utm_campaign=v3

¹⁸

[https://www.amazon.com/gp/product/B01HS1PTK4?tag=ttr_gps-tracker-20&ascsubtag=\[site|ttr|cat|928|art|NA|pid|54242|tid|NA|bbc|NA](https://www.amazon.com/gp/product/B01HS1PTK4?tag=ttr_gps-tracker-20&ascsubtag=[site|ttr|cat|928|art|NA|pid|54242|tid|NA|bbc|NA)

Trackimo¹⁹ (discussed below). A similar report entitled '5 of the Best Personal GPS Tracking Devices' was published by *Gadgetreview* in 2016²⁰ (featuring Trax and Pocketfinder, discussed below).

- **GPS Defender Asset**²¹

The GPS Defender is intended for people and asset tracking. It is a portable and compact device which can be carried in the pocket, hidden in a bag or luxury goods (such as cameras). The device provides optimised operation and scheduled reports. It incorporates a timer, which contributes to preserving battery power. This feature allows it to remain in deep-sleep mode for long periods (especially when stationary). This device also incorporates a motion sensor which activates when it is moved, triggering the process of sending out its location on a preset regular basis over the mobile phone data network to the provider's dedicated online tracking platform ('Futuretrack') at intervals as little as every 15 seconds. It only transmits location reports (via a cellular network) according to a pre-defined schedule, typically when it is moving. Users can access the location information via a web-based browser or mobile phones/tablets.

- **Techsilver GPS Tracker**²²

Techsilver provides a range of GPS trackers, which include the GPS SmartSole Location Tracker, 'smart' sole inlay which fits into a shoe.

- **Personal Mini Spy GPS Tracking Device**²³

The device incorporates a D-GPS receiver and mobile cellular technology (with a claimed accuracy of 3 metres). Multiple tracking modes allow on demand location reporting or as often

as every 10 seconds (or any other duration). A 'geofence' feature allows the user to specify a geographical zone ('fence'). The device will alert the user if it moves out of the geofence zone.

- **Trax**²⁴

Trax offers one package which includes two different clips (albeit only one tracker), one for clothing and one for a collar, indicating the company's different approaches for tracking children and pets. The user can create schedules, design their own geofences or proximity fences, and set up automatic alerts for unexpected behaviours. Trax claims to have a unique augmented reality feature linked to a mobile phone camera.

- **Spot Gen3**²⁵

Spot Gen3 is aimed at hikers and adventuring enthusiasts. It has no screen and links to other mobile devices. The device tracks where it is, records where it has been, allows the user to check in at specific locations and has the ability to send pre-planned messages and SOS signals.

- **DeLorme InReach SE**²⁶

The device has a tiny screen and basic direction buttons which can be used to send text messages, as well as SOS capabilities. Battery life is claimed to be 100 hours.

- **Amber Alert GPS**²⁷

This device provides safety-based tracking and is aimed at parents who want to track their children. In addition to tracking, the device also allows two-way communication which can be activated with a single button. It connects to a smartphone app.

¹⁹ <https://trackimo.com/tracking-people-with-trackimo/>

²⁰ <http://www.gadgetreview.com/5-of-the-best-personal-gps-tracking-devices>

²¹ <https://www.spyequipmentuk.co.uk/gps-defender-asset-people-tracker>

²² https://techsilver.co.uk/product-category/assistive-technology/gps-dementia-trackers-sos-alarms/?gclid=C17izqjMxdMCFY8y0wodR_APzQ

²³ <https://www.amazon.com/Personal-Tracking-Device-Children-Vehicle/dp/B008980N7K>

²⁴ <http://www.gadgetreview.com/5-of-the-best-personal-gps-tracking-devices>

²⁵ <http://www.gadgetreview.com/5-of-the-best-personal-gps-tracking-devices>

²⁶ <http://www.gadgetreview.com/5-of-the-best-personal-gps-tracking-devices>

²⁷ <http://www.gadgetreview.com/5-of-the-best-personal-gps-tracking-devices>

- **PocketFinder**²⁸

PocketFinder offers product options for people (including children, teenagers and seniors), pets and vehicles. The device has an app which overlays maps with the locations of multiple people, and allows geofencing.

- **Ping**²⁹

Ping is a waterproof miniature tracker, which can send a signal from the US, Canada and Mexico to a mobile phone. It can be used for people, pets and assets. The device has a GPS tracker, Bluetooth for smaller distances and 3G cellular connection through which it communicates.

- **hereO GPS watch for children**³⁰

The GPS-based hereO smartwatch for children allows GPS tracking. It has a geofencing feature and will send alerts if they wander out of 'safe zones'. The watch has a built-in SIM card and supports connectivity in more than 120 countries.

- **Unforgettable Personal Alarm and GPS Tracker**³¹

The GPS tracking device is aimed at people with memory loss and dementia who may get lost when venturing outside. The device is waterproof, allows geofencing and two-way calling for emergency contacts by pressing the SOS alarm button. It also incorporates a motion sensor which can detect if the user has fallen.

- **Jimilab trackers**³²

Jimilab (China) offers a range of GPS-based trackers for people and assets, vehicle navigation as well as home monitoring. The personal tags have 'panic buttons' which an individual can activate if they are in trouble. Tags can be mounted on lanyards, on safety helmets and belt attachments, for example.

- **Trackimo trackers**³³

Trackimo offers a range of GPS-based trackers for people, animals and assets. The devices can also record the speed at which drivers are travelling. It allows geofencing and incorporates an SOS alert button, which sends a message via SMS or email when activated.

3.2 Smartphones

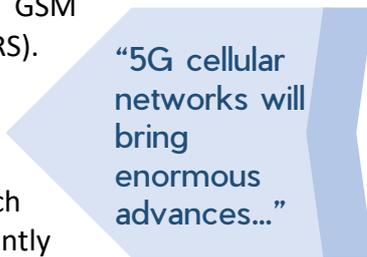
3.2.1 Global System for Mobile Communications (GSM)

Mobile phones (and other mobile devices as well as some trackers and navigational devices) communicate via cellular networks³⁴.

A number of different protocols are used, mostly digital. GSM (Global System for Mobile Communications) was originally developed as a standard to describe the protocols for second-generation (2G) digital cellular networks. It has now been adopted as the de-facto global standard for mobile communications – with over 90% market share, operating in over 219 countries.

2G networks were developed as a replacement for first generation (1G) analog cellular networks. This GSM standard originally described a voice telephony system. Over time, GSM has been expanded to also include data communications, and included protocols such as packet data transport via GPRS (General Packet Radio Services) and EDGE (Enhanced Data rates for GSM Evolution, or EGPRS).

Third-generation (3G) UTMS standards followed, which were subsequently superseded by fourth-generation (4G) LTE Advanced standards. Fifth



“5G cellular networks will bring enormous advances...”

²⁸ <http://www.gadgetreview.com/5-of-the-best-personal-gps-tracking-devices>

²⁹ <http://readwrite.com/2017/02/22/ping-gps-locator-dl4/>

³⁰ <http://thegadgetflow.com/portfolio/hereo-gps-watch-kids/>

³¹ <https://www.unforgettable.org/personal-alarm-gps-tracker?gclid=CMPrjOfLxdMCFcluGwodAJ0Gog>

³² <http://www.jimilab.com/products/personal-gps-tracking-device.html>

³³ <https://trackimo.com/tracking-people-with-trackimo/>

³⁴ <https://en.wikipedia.org/wiki/GSM>

generation (5G) cellular networks will be introduced during the next few years, and will bring enormous advances, including in bandwidth and speed.

In order for a device to use a cellular network, it requires a SIM (Subscriber Identification Module) card.

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3.2.2 Smartphones with GPS

Mobile phones can be used for tracking and identification – keeping in mind that what is tracked is the phone, which may or may not be with its owner.

GPS receivers are embedded in smartphones, and essentially used for similar purposes than the dedicated navigational devices described above, as well as for a myriad of other applications which require real-time geospatial location information. The ability to track the position of the mobile phone is now a fairly standard feature.

Smartphones equipped with GPS receivers can transmit data via cellular networks, wifi networks and bluetooth. Many phones also have near field communication (NFC) capabilities, which can be used for mobile ‘touch’ payments.

Many smartphones have Assisted GPS (A-GPS), which essentially does the same thing as D-GPS, by switching to intermediate servers in case of disconnection with GPS satellites.

Smartphones usually have map apps, which show location information in a graphical format and which can also be used for route guidance. A number of mobile phone apps are used specifically for tracking, with some aimed at sharing location with friends and family^{35,36}. These are typically used in a cooperative mode.

There are a number of apps available which can be installed in smartphones aimed at tracking the user without the latter’s knowledge^{37,38}

(and hence in a non-cooperative mode). Some of these apps also offer additional ‘benefits of remote monitoring’, including remote tracking of call logs, texts and email messages, accessing browser history, access to contact information and reading of messages on social media accounts.

There are a numbers of reasons why dedicated trackers and navigation devices may be preferred over smartphones for navigational and tracking purposes, including:

- Suitability for use in industrial settings, and the need for specialised features.
- The costs of mobile phones are higher than dedicated devices, and parents may not want children to carry mobile phones just for the purpose of tracking.
- Dedicated devices can be more discreetly carried (by children, for example).
- Longer battery life.

Gyroscope and accelerometer sensors

Rice University³⁹ recently reported experimental results using data from gyroscope and accelerometer sensors in mobile devices (such as smartphones) to determine location positions in buildings (where GPS signals can be problematic and quickly deplete battery power). The sensor information is processed with artificial intelligence algorithms to filter out ‘noisy’ signals from irrelevant movements (such as hand waving). The research team claims to have demonstrated a solution that is twice as accurate as GPS services, with significantly better performance in terms of energy usage.

³⁵ <http://www.peopletrackerapp.com/>

³⁶ <http://blog.atlasrfidstore.com/what-is-rfid>

³⁷ <https://safeguarde.com/remaining-discreet-using-people-tracker-app-monitor-someone/>

³⁸ <https://safeguarde.com/spy-text-messages-cell-phone-get-information-needed/>

³⁹ <https://phys.org/news/2017-04-indoor.html>

3.3 RFID

3.3.1 How RFID works^{40,41,42}

Radio-Frequency Identification (RFID) technology uses electromagnetic (EM) waves (and energy) to communicate with RFID tags, triggering a unique signature (identification information stored in a microchip in the tag). This enables the tag to be identified. RFID technology operates in one of three RF frequency bands, which determines the operating characteristics. An RFID system has four main types of components, viz. tags (which can be uniquely identified), readers (which interrogates and identifies the tags) and antennas (in the tags and also connected to readers); as well as a computer to control the system and process information.

Advantages and features of RFID include⁴³:

- Doesn't need line of sight.
- Tags are able to be rewritten and reused.
- Tags can be extremely durable against impact and environmental factors.
- Tag data is encrypted and can also be locked for extra security.
- Readers can read hundreds of tags within seconds.
- Tags can have information printed on them like instructions, barcodes, or company names.
- Systems can be integrated with other internal systems or processes.

The widespread availability of 3D printing is enabling new options for mounting RFID tags⁴⁴.

For all its advantages and features, it is also important to recognise what RFID cannot do and what it is not. RFID does not by itself determine its position as does GPS. It determines the location of a tag by responding to a reader, which then registers that the tag is

in the vicinity of the reader (mindful that the location of the reader is known). RFID tags can hold a limited amount of information and the ranges from which they can be read are relatively limited.

3.3.2 RFID tags

RFID tags contain an antenna to receive and transmit the EM waves, and an electronic chip which contains the identification information. The tags can be either passive or active.

Passive tags operate in a transponder mode. They have no internal power source and are powered by the energy in the illuminating EM wave transmitted by the reader. They wait to be interrogated by the reader. The energy in the illuminating EM wave then 'wakes up' the tag, which then responds by transmitting its unique signature, which in turn is read by the reader.

Active tags, on the other hand, contain their own batteries. They can operate in a 'beacon mode' where they transmit their unique signatures without waiting to be interrogated by a reader, or in a 'transponder' mode where they wait to be interrogated before responding. Semi-active tags (also known as 'battery assisted passive' (BAP) tags) include a battery in order to always have sufficient energy to turn on, but not enough to be active transmitter. BAP tags have greater range than passive tags although at a higher cost and limited life due to the battery.

New technology enabling smaller tags were recently reported⁴⁵. Because these RFID tags no longer need to convert alternating current (AC) to direct current (DC) in order for the tags to function effectively, they can be 25% smaller and less expensive.

⁴⁰ <http://blog.atlasrfidstore.com/rfid-tag-basics>

⁴¹ <http://blog.atlasrfidstore.com/what-is-rfid>

⁴² <http://blog.atlasrfidstore.com/active-rfid-vs-passive-rfid>

⁴³ <http://blog.atlasrfidstore.com/what-is-rfid>

⁴⁴

<http://www.professionalsecurity.co.uk/products/integrated-systems/people-tracker/>

⁴⁵

https://www.nsf.gov/news/mmg/mmg_disp.jsp?med_id=81683

RFID tag frequency bands

Low frequency (LF)

Passive tags in the frequency range: 125 -134 kHz

Read range: contact to about 10 cm

Typical applications: access control, car key-fobs, applications with high volumes of liquids and metals; tracking of animals (because the tags can be read through the animals' bodies, which contain fluids).

High frequency (HF)

Passive tags in the frequency range: 13.56 MHz

Read range: contact to about 30 cm

Typical examples: Library books, personal ID cards, passports

HF waves can pass through most materials, except water and dense metals.

Ultra-high frequency (UHF)

Sensitive to liquids and metals

Passive tags in the frequency range: 856-960 MHz

Read range: contact – 6 metres, with larger tags – 30 metres

Typical applications: high volume manufactured goods, electronic tolls, race timing, asset tracking.

Passive UHF RFID systems use passive backscatter modulation (as opposed to magnetic coupling used by LF and HF systems).

Active tags in the frequency range: 433 MHz and 915 MHz (in the 856-960 MHz band)

Read range: 30 – 100+ metres

Typical applications: automobiles, hazardous industrial environments

Active tags operate in a transponder or beacon mode, rather than using backscatter or coupling to communicate. The tags can also incorporate

other technologies such as WiFi, Bluetooth and GPS), as well as sensors which can detect environmental conditions (such as temperature).

Microwave band (2.45 GHz and 5.8 GHz) tags have also been reported.⁴⁶

One of RFID's advantages is speed and flexibility. When the priority is completing a transaction quickly, RFID is a good choice. With regard to flexibility, detection ranges can be varied and RFID information can be integrated into other databases.

RFID is a technology which determines presence rather than identity; if an RFID-enabled badge is transferred from one person to another (either intentionally or unintentionally), their identities will also be swapped. In order to counter this, the use of other technologies in addition to RFID can be helpful.

When used in conjunction with other technologies, RFID can be a very effective tool for smart authentication and identification of people and assets. RFID technology can be combined with other technologies such as cloud computing, mobile technology, biometrics and IoT for greater impact. This provides an entirely new layer of security, which allows more secure authentication linked to unique identity.

A number of recent articles reported on the copying and cloning of proximity devices, including RFID tags⁴⁷; as well as technologies and techniques to capture, copy and clone contactless cards and other RFID-type devices^{48,49}. A number of shielding systems to protect credit cards from being cloned whilst carried by a user have been reported, including a trackable wallet with shielding^{50, 51, 52}. A smart

⁴⁶ <http://blog.atlasrfidstore.com/rfid-tag-basics>

⁴⁷ <https://blog.getkisi.com/copy-clone-prox-hid-id-card/>

⁴⁸ <http://www.coolsmartphone.com/2016/12/07/capture-and-clone-contactless-cards-easily-be-a-thief-easily/>

⁴⁹ <https://blog.nviso.be/2017/01/11/a-practical-guide-to-rfid-badge-copying/>

⁵⁰ <http://wonderfulengineering.com/will-never-loose-wallet-eksters-ultra-slim-trackable-wallets/>

⁵¹ <http://krisannehall.com/product/iphone-6-android-rfid-blocking-cell-phone-privacy-case-copy/>

⁵² <https://shop.komando.com/everything-apple/1205-smartphone-shield.html>

wallet⁵³ incorporates a specially designed RFID-blocking lining to ensure that card information is secured from any passer-by.

3.3.3 Near Field Communication (NFC)

Near Field Communication (NFC)^{54,55} is a specialised application (subset) of RFID, operating in the HF band at 13.56 MHz. NFC devices can act in passive or active modes. Passive devices have no power sources and can only connect to active devices.

Active devices (such as smartphones) can send and receive data. Full NFC devices are capable of being both an NFC reader and an NFC tag, which allow them to communicate peer-to-peer (i.e. a separate reader device is not required, a feature distinguishing NFC devices from other RFID systems). The read range is typically a few centimetres. NFC is a secure form of data exchange, which enables their use in contactless payment systems. It can also be used for social networking, for sharing contacts, photos, videos or files, and can act as electronic identity documents and key cards⁵⁶.

A full NFC device can work in three modes, viz.

- NFC card emulation mode, which enables NFC-enabled devices such as smartphones to act like smart cards, allowing users to perform transactions such as payment or ticketing.
- NFC reader/writer mode, which enables NFC-enabled devices to read information stored on inexpensive NFC tags embedded in labels or smart posters.
- NFC peer-to-peer mode, which enables two NFC-enabled devices to communicate with each other to exchange information.

⁵³ <http://thegadgetflow.com/portfolio/woolet-smart-rfid-wallet/>

⁵⁴ <http://blog.atlasrfidstore.com/rfid-vs-nfc>

⁵⁵ <http://blog.atlasrfidstore.com/nfc-facts-applications>

⁵⁶

https://en.wikipedia.org/wiki/Near_field_communication

3.3.4 Examples of RFID products

In the section below, a number of RFID-based products are briefly discussed, mainly to illustrate examples of the type of products that are available and different features used.

• The Identec tracking system for use in hazardous work environments^{57,58}

Accurately monitoring the whereabouts of workers is an important safety consideration. Identec offers RFID-based personnel tracking systems specifically for hazardous industrial sectors such as oil and gas, ports and terminals, mining and tunnelling as well as automotive⁵⁹. In these environments safety concerns pertaining to extreme temperatures, fires, explosions and catastrophic events such as nuclear leaks present high risks.

The company offers specialised products for use on offshore oil rigs⁶⁰ - the modular Identec Solutions Watcherpersonnel system. It is claimed that the system 'delivers real-time visibility of personnel to maximize safety, security and productivity on offshore platforms..... significantly improves personnel safety' and '... ensures the highly efficient handling of evacuation situations and increases safety in day-to-day operations'. The company mentions deployment of their technology on oil rigs in European waters.

Identec's Watcherpersonnel system is fully scalable and customisable with a number of optional integrated modules. It is based on the proprietary TrailBlazer backbone, and provides users with automated personnel safety, access control systems and workflow optimisation solutions. The company claims that their solutions are built on the "Norwegian Oil & Gas Association (OLF) guidelines and best practice

⁵⁷ www.identec.com

⁵⁸ <http://blog.atlasrfidstore.com/extreme-reads-rfid-oil-rigs>

⁵⁹ <https://www.identecsolutions.com/>

⁶⁰ <https://www.identecsolutions.com/oil-gas-industry-solutions/watcher-personnel-people-tracking/>

industry business cases, to enable value creation in all solutions provided”.

Identec’s tracking system allows locating workers within zones rather than pinpointing exact whereabouts. The company claims that its clients prefer not have very accurate information about the location of employees in consideration of their privacy concerns. Other considerations include technological redundancy, in case there are system failures when the network shuts down in emergency situations.

- **IQ People Tracker**⁶¹

The IQ People Tracker RFID-based system is aimed at rugged industrial environments such as mining, construction, manufacturing, ports and emergency services. It is claimed that the system ‘accurately determines direction, at high speed, for hundreds of people at a time’. The receiving points are 3G and solar with active cooling. Receiving antennas can be mounted in mats over which people walk. Individual tags are active RFID transmitters, are ruggedized and can be mounted in lanyards, clip-on tags, clothing (such as helmets) or attached to swipe cards. Interesting features include the ability to disable dangerous equipment (such as forklifts) when non-authorized people are in close proximity. In the event of an emergency, the system can determine if all personnel are at a muster point, and locate those that are not.

- **Real Time Location Tracking Solutions**⁶²

Real Time Location specialises in accurately tracking/locating people and assets in real-time when they are within or close to buildings. Application include security, manufacturing, logistics, pharmaceutical, education, retail, engineering, healthcare, data centres,

corporate buildings, public buildings, government buildings, correctional facilities, guard tour management and access control.

Battery powered active RFID tags continually broadcast an identifier signal every 1.2 seconds, which uniquely identifies all personnel and/or asset in the system. Wireless Location Modules (WLM) are strategically located within and around the buildings and detects tags within specific zones/areas. The zone of each beacon can be adjusted to read badges/tags from 0.5 metres up to 50 metres. RFID readers receive signals from any number of location beacons within their read zone. A web-enabled tracking application software runs on computers and mobile devices.

- **GAO Personnel Tracking System**⁶³

A fully integrated personnel tracking solution with the ability to monitor personnel in real-time.

- **ADEC people tracking system**⁶⁴

The ADEC system tracks and counts people anonymously within polygonal zones (within for example, arrival halls of airports, shopping malls, etc) which can be defined by the operator. Sensors are mounted overhead at strategic locations, and are connected via Ethernet. Each person within the designated ‘field of view’ is anonymously designated a unique track-ID. The person’s movements are then tracked and logged (within 20 cm) during the time they are in the field.

- **Gatria car tag**⁶⁵

The Gatria RFID tag can be hung on a vehicle’s rear view mirror, providing fast and reliable RFID detection and identification in a portable and reusable form factor. It is useful in applications requiring temporary or portable vehicle identification functionality, and provides a solution for customers looking for a reliable,

⁶¹ <https://www.ramprfid.com/wp-content/uploads/2014/07/IQ-People-Tracker-Data-Sheet.pdf>

⁶² <http://realtimelocation.co.uk/>

⁶³ <http://gaorfid.com/people-locating-rfid-system/>

⁶⁴ https://adec-technologies.com/fileadmin/user_upload/downloads/ brochure/ADEC_Observer_enUS_0114_LR.pdf

⁶⁵ <http://www.rfidworld.ca/new-rfid-car-hang-tag-secures-parking-identification-access-control/2684>

automated system for short-term or temporary vehicle identification applications.

- **Humanyze**⁶⁶

The company's mission is to 'redefine smart buildings'. The Humanyze ID tag incorporates RFID, NFC and Bluetooth technology as well as infrared sensors to track face-to-face interactions, an accelerometer and two microphones. The aim is to combine biometric analysis and analytics with traditional ID badge technology. The ID tags communicate with beacons around the office, which enables the system to determine the location of employees. The microphones do not have the ability to record conversations, but can measure the tone, volume and speed of conversation, and potentially stress levels. Data is aggregated and presented in an anonymous format to managers who can use it to gain insights into their teams.

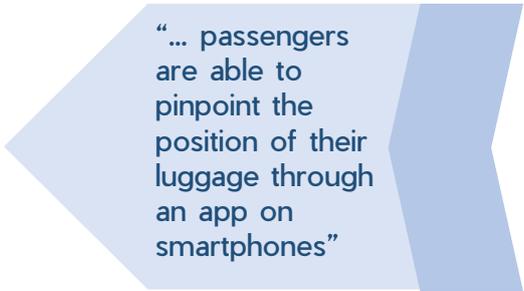
- **Airline luggage tagging**

Traditionally airline baggage has been tagged using barcode technology - not without challenges, since the tag on each piece of baggage needs to be read individually with a barcode scanner. This is an inconvenient and labour intensive process, particularly if the tag is difficult to locate. In addition, tags can be become torn, lost or smeared, which can lead to baggage misplacement and loss.

Delta Airlines^{67,68} moved away from barcoded tags on luggage to a new RFID-based system early in 2017. It is expected that the number of the airline's lost and mishandled bags will be reduced by 25%. Delta claims that within the first couple of months of use, it has achieved 99.9% accuracy with RFID tracking, up from the airline's bar-code accuracy figures of between 85% and 97%. In addition, passengers are able to pinpoint the position of their luggage through an app on smartphones. RFID tags enables

better automatic baggage handling, and allow remote reading (even an entire room full of bags simultaneously).

RFID technology for airline luggage is not new. McCarran International Airport in Las Vegas, for example, has been using RFID tags to track all baggage since 2005. It claims that whereas the



"... passengers are able to pinpoint the position of their luggage through an app on smartphones"

industry standard for accuracy of bar-code scanning of bag tags is 80% to 95%, the RFID system at the Las Vegas airport is accurate 99.5% of the time. Qantas has used RFID tags for luggage of frequent fliers within its domestic network since 2010.

- **Passive RFID tag with extreme range and bad weather capability**⁶⁹

RFID Canada, a provider of RFID tags and readers offers a UHF Battery Assisted Passive tag which provides performance in industrial, logistics, transportation and any other rugged environments requiring the ability to read a passive tag at ranges which are beyond what the standard passive tag will provide – up to 60m range.

3.4 Bluetooth

Bluetooth is a short-range wireless connection operating in the UHF ISM band (2.4GHz to 2.485 GHz). The range is short, about metre or so. Bluetooth is typically used to electronically connect devices wirelessly, enabling them to communicate over short distances.

⁶⁶ <http://www.digitaltrends.com/home/smart-sensors-in-the-workplace/>

⁶⁷ <http://www.travelpulse.com/news/travel-technology/delta-s-app-puts-the-magic-of-bag-tracking-in-your-hands.html>

⁶⁸ <http://www.travelweekly.com/Travel-News/Airline-News/RFID-technology-expected-to-reduce-lost-baggage-by-25-percent>

⁶⁹ <http://www.rfidworld.ca/new-passive-rfid-tag-provides-extreme-read-ranges-operates-in-extreme-weather/2488>

Bluetooth trackers have been on the market for some years. They have become smaller and thinner due to advancements in Bluetooth chips and software. The cost to build a Bluetooth tracker has also declined as smartphones, tablets and many computers include the technology by default.

If a Bluetooth tracker is Wi-Fi compatible as well, it allows the tracker to connect to open wireless internet connections, providing a boost to the tracker's reception if it is indoors.

In the section below, a Bluetooth-based product is briefly discussed to illustrate an example of the type of products that are available and different features used.

- **TrackR⁷⁰**

TrackR produces a range of Bluetooth tracker devices which can be attached to a myriad of devices – from pens to car keys to handbags to bicycles – allowing them to be found when lost. An app on a smartphone shows the device's last known location. Users can also locate devices through the Geozilla app.

The company is working with a provider of WiFi infrastructure to add Bluetooth connectivity in existing municipal hotspots. The intention is to create the ability to track city assets such as community bicycles. Existing TrackR devices will also be able to access this system, allowing users to pinpoint lost items even if no other TrackR app users have been nearby.

The company claims that Bluetooth is not as cost-prohibitive as GPS, which requires more expensive hardware and an ongoing cellular data plan for each device, and is more effective than RFID tags, which can only detect items that are inches away.

⁷⁰ <https://www.fastcompany.com/3069233/bluetooth-trackers-and-the-race-to-help-you-find-your-stuff>

⁷¹ <https://gigaom.com/2013/09/10/with-ibeacon-apple-is-going-to-dump-on-nfc-and-embrace-the-internet-of-things/>

⁷² <http://www.ibeacon.com/>

3.5 Bluetooth Low Energy (BLE)

iBeacon^{71,72} is a technology developed by Apple and announced in 2013. The system uses Bluetooth Low Energy (BLE) technology. Essentially it creates regions around beacons, which can be detected by smartphones (and other devices) running appropriate apps. The iBeacons are small wireless sensors. To some extent iBeacon can be considered to be a competitor technology for NFC, having an advantage when it comes to range.

A typical iBeacon application can be an enhancement of the shopping experience. iBeacons will transmit smart coupons to shoppers' iPhones for example, and walking directions to aisles where specific products are located. It was estimated in December 2015 that beacons will deliver 1.6 billion coupons by 2020⁷³.

iBeacon also allows payments with a smartphone. Crosscan produces a WLAN-iBeacon system⁷⁴.

3.6 Radio Tomographic Imaging (RTI)⁷⁵

Radio tomographic imaging (RTI) can be used to detect the presence of people, specifically through walls. It does not identify individuals, but can detect their presence. They do not need to wear tags or chips. The RTI system surrounds the area to be monitored with a perimeter of wireless-network nodes, each of which compares signal strengths from all the others. When the data from all nodes is assembled, radio-blocking objects such as human bodies can be located to within a metre. This can be done with the radio nodes placed on the other side of walls from the area where the human target is.

⁷³ <http://www.ibeacon.com/juniper-research-beacons-to-deliver-1-6bn-coupons-by-2020/>

⁷⁴ <http://crosscan.com/de/wlan-ibeacon.html>

⁷⁵

http://www.theregister.co.uk/2009/10/12/utah_through_walls_by_zigbee/

“Applications include dangerous situations where police or firefighters need to enter a building...”

Applications include dangerous situations where police or firefighters need to enter a building. Before doing so, they would throw dozens of the RTI transmitters around the building and would then immediately be able to see a computer image showing where people are moving inside the building.

3.7 Thermal sensing and imaging

The VCA IPT-1000MR Intelligent People Tracker⁷⁶ provides a way for retailers to minimise queuing times at checkouts. The system employs an infrared sensor and specially designed lens, and uses analytics process information, combining 3D imaging with footfall analysis software. It offers a method of measuring customer-waiting times at the point of sale or ATMs, and can send real-time alerts to managers when queuing time or queue lengths exceed pre-defined thresholds. Whilst monitoring stationary queues, it can detect customers who ‘give-up’ and walk away.

VTT is piloting a tracking system⁷⁷ using depth camera technology ((infrared laser, a light-sensitive cell, and 3D image processor) in shops and apartments for seniors. The system distinguishes people from other moving objects and tracks their movements, but does not identify people individually. The information analysed from depth data is provided as coordinates (rather than video images) and analyses behavioural information. Applications include measuring the flow of people in shops

⁷⁶

<http://www.professionalsecurity.co.uk/products/integrated-systems/people-tracker/>

⁷⁷ <http://www.vttresearch.com/Impulse/Pages/Tracking-people.aspx>

and monitoring the use of facilities such as lecture theatres and video conferencing facilities to determine how many people are actually using the facilities; as well as safety of elderly living alone. The system can learn what people’s ‘normal’ behaviour patterns are, and then report out of the ordinary behaviour.

3.8 LiFi⁷⁸

LiFi is a light-based system. In one application, LED light bulbs in a very large supermarket flicker at a very high frequency, much faster than the eye can detect. Each light bulb transmits its own pattern. The camera in a customer’s mobile phone detects the signals and then decodes its position in the shop. An entire LiFi mini-internet system can be set up in this way, since the light waves can carry significant amounts of information. Light cannot penetrate walls, hence the system has an innate security feature in being contained to a single room enclosed by walls.

3.9 Chip implants in employees

There have been a number of recent reports pertaining to employees in companies that have volunteered to implant NFC chips in

“employees in companies are volunteering to implant NFC chips...”

their bodies - known as biohacking. It is estimated that circa 10,000 people worldwide have such chip implants. Implant kits can be bought online, and include a sterile injector with a pre-loaded chip and gauze for wound care. Although the chips are claimed to be biologically safe, questions regarding ethics, legalities, privacy and security are being raised.

⁷⁸

<https://www.theatlantic.com/technology/archive/2016/11/how-light-bulbs-watch-you-buy-groceries/508061/>

Epicenter is a start-up incubator in Sweden^{79,80}. More than 150 employees in the centre have volunteered to have RFID chips implanted. The chips are used to identify employees and replace conventional ID cards (similar to chip implants in pets). The chips are about the size a grain of rice and are implanted by syringe in the fleshy part of the hand next to the thumb. The chip allows employees to open doors by merely waving their hand in front of the door's sensor. The same technology can be used for printing, paying for food, logging onto computers and starting cars. The chips are apparently not used to track the movement of employees, but rather as identification to activate devices.

A marketing company in Belgium, NewFusion, also offers its employees the opportunity to get chipped in a similar way^{81,82}.

A manufacturer of breast-implants (Establishment Labs) announced in 2013 that its products would be supplied with RFID tags⁸³, which would be implanted into patients with the breast-implants. This would enable the doctor and patients to ensure the exact model of the implant, eliminating the need to rely solely on the doctor's notes. The RFID tags in the implants in the patient's body can be read through skin and body tissue to identify the implant. In another development Faxitron⁸⁴ announced in April 2017 that the Food and Drug Administration (FDA) in the US has approved its RFID-based products for breast lesion localisation, which will provide more precise guidance for breast surgery. The technology eliminates complications presented by older

technologies by using a non-radioactive, proprietary tag enabling the surgeon to remove the correct area of breast tissue during an operation.

3.10 Biometric identification

Various systems of biometric identification are used. They rely on the fact that an individual has a number of unique biometric features which can be used as the basis for identification, including fingerprints, voice, facial features, retina and DNA. Although biometric monitoring of employees appears to be growing, adoption is constrained by privacy, ethical and legal concerns, including hacking risks.

3.10.1 Fingerprint and ambient sensors

Biometric identification using fingerprints has been in use for some time. Scanners are available for physical access control. A number of smartphones and computers also have fingerprint recognition technology to provide access to the devices.

It was recently reported that Mastercard is introducing fingerprint sensors to payment cards^{85,86}, combining it with a 4-digit PIN. The sensor is a small, thumbnail-size rectangular patch located at the top right corner of the card. It is easily accessible when the card is inserted into an ATM machine or payment terminal.

Visa payment cards is exploring 'ambient authentication'⁸⁷, for use with mobile phones. Between 100 and 200 'vectors' are measured to determine whether the person using the device is the owner, including pressure on the screen, the way the keys are used, range of motion,

⁷⁹ <https://venturebeat.com/2017/04/11/swedish-tech-hubs-move-to-implant-people-with-microchips-makes-me-queasy/> and

<http://www.latimes.com/business/technology/la-fi-tn-microchip-employees-20170403-story.html>

⁸⁰ <http://www.digitaltrends.com/cool-tech/epicenter-office-of-the-future/>

⁸¹ <http://www.dailymail.co.uk/sciencetech/article-4203148/Company-offers-RFID-microchip-implants-replace-ID-cards.html>

⁸² <http://www.euronews.com/2017/02/14/chips-in-the-hand-to-identify-who-we-are>

⁸³ <http://www.rfidjournal.com/articles/view?11093>

⁸⁴ <http://www.businesswire.com/news/home/20170428005968/en/Faxitron-Announces-Localizer%e2%84%a2-Radiofrequency-Identification-System-Granted>

⁸⁵ <https://www.engadget.com/2017/04/20/mastercard-biometric-fingerprint-card/>

⁸⁶ <http://interestingengineering.com/mastercard-reveals-next-generation-card-with-built-in-fingerprint-reader/>

⁸⁷ <http://www.ibtimes.co.uk/visa-sees-ambient-authentication-future-social-payments-1618688>

predominant hand and average amount of charging during the day. If the screen is on, facial recognition can be made at a rate of three of four times per second while the payment is being conducted.

3.10.2 Voice recognition

Voice recognition is becoming increasingly sophisticated, driven in part by the growing trend of users ‘having conversations’ with their mobile devices⁸⁸. There is an increase in voice interaction and searches, and as well as

“... growing trend of users ‘having conversations’ with their mobile devices”

in the nature of the interaction. It is estimated that between 20% and 25% of queries on the Google mobile app and Android

devices are voice searches, with 60% of voice searchers reporting that they started using virtual assistants (Siri, Alexa and others) during the past year. It is estimated that 50% of all searches will be voice searches by 2020. Users also tend to use conversational full sentences when ‘speaking to’ their devices, rather than just using key words.

- **Pindrop fraud detection**⁸⁹

Pindrop, an Atlanta-based company, which primarily offers sound-based fraud detection tools for call centres, plans to release a service which allows connected devices to verify who they are talking to, turning the human voice into a combination of a username and password.

- **Google Home**⁹⁰

Previously, Google Home only linked up to the account of whomever set it up first. In the future, the device will be able to handle multiple

⁸⁸ <https://martechtoday.com/voice-search-data-two-trends-will-shape-online-marketing-2017-196949>

⁸⁹ <https://www.fastcompany.com/3068395/how-a-security-company-learned-to-recognize-the-sound-of-fraud>

⁹⁰

<http://www.chicagotribune.com/bluesky/technology/ct-google-home-voice-id-20170420-story.html>

accounts and determine who it is speaking to. The ability to identify an individual's voice may also help cut down on some unwanted surprises – mainly by preventing others from buying on your account.

3.10.3 Facial recognition

A number recent developments in facial recognition have been reported, including a system to identify people in crowds⁹¹ and an app-based system for clinicians using facial recognition⁹².

As identification systems become more sophisticated, fraudsters will continue to attempt to find ways around the new security features. In order to fool facial recognition systems, techniques are being developed to morph faces on ID documents. The idea is to use a graphically morphed photograph on an ID document, so that it looks sufficiently like two people. Both individuals can then (fraudulently) use the same ID document⁹³.

3.10.4 ‘Direct from the brain’

It has been reported that Facebook is exploring the development of technology to ‘read people’s minds’ so that they can ‘type directly from the brain’. It was reported that using brain implants, people can already type

“... type directly from the brain”

eight words a minute. A video played at a conference showed two Facebook employees talking to each other through touch. It will be interesting to see if these technologies can also be used to identify people.

⁹¹ <https://www.fastcompany.com/3069264/congress-fbi-face-recognition-real-time-street-lineup>

⁹² <http://www.mobihealthnews.com/content/fdna-launches-app-based-tool-clinicians-using-facial-recognition-ai-and-genetic-big-data>

⁹³

<http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0173319>

3.11 Sharepoint

People Location Tracker⁹⁴ is an app for Microsoft SharePoint Server 2013. It tracks the location of employees and shows their location as markers on a Google Map when they visit one or more SharePoint pages. The app also shows the time when a person was last seen at a particular location.

3.12 Other technologies

Other related technologies not discussed in this report include barcoding and swipe cards with magnetic strips.

4. Discussion

The vantage point of **DeltaHedron's** reports is one of exploring the strategic business opportunities, threats, risks and impact presented by emerging technologies and technological change. This report examines a number of technologies and products to 'track people'. One of the main aims of the report is to investigate tracking of employees in hazardous industrial settings. However, the study covers a broader spectrum of technologies and applications, including tracking and identification of people in other contexts as well as assets and animals.

A range of products are available to track people in a number of diverse work environments, including hazardous industrial settings such as offshore oil rigs, mines, factories and ports as well as for office environments and for tracking and identifying employees who are offsite or travelling. The solutions offered typically include the tracking and identification technologies as well as software systems used for control and analysis of the information and related services.

The choice of technology for tracking and identifying employees will depend very much on

the requirements of the application, as well as the nature of the work environment and the physical surroundings, external environmental factors, the degree of ruggedness required and hazardous factors which need to be accounted for.

Many products are based on established RFID, GPS and Bluetooth technologies, as well as variations on the themes such as Near Field Communication (NFC) and iBeacons. All of these have their strengths and weaknesses, and no one technology is ideal for all applications. A number of recent publications refer to continuous enhancements, including extension of range and battery life as well as accuracy of location. A number of the products on the market based on the established technologies also utilise more than one technology to compensate for the strengths and weaknesses of the various technologies.

Recent reports in the public domains refer to a number of other technologies which are also used for tracking and identification. These include radio tomographic imaging (RTI), thermal sensing and LiFi. A range of biometric technologies are used, including voice recognition, fingerprint recognition, facial recognition and retina scans. Experimental work is being done on the use of brain waves. A number of cases have been reported where employees implanted RFID chips in their bodies.

In addition to applications aimed at tracking employees, many products focus on other diverse segments of people such as children, the elderly, people with Alzheimer's disease and dementia, shoppers, mountain climbers and adventurers. Each of the products has a number of features which can provide benefits for the segment at which it is aimed, including 'geofencing' (where the device will send an alert if it moves out of defined geospatial region) and the ability to communicate via voice or text

⁹⁴ <http://spdeveloper.co.in/apps/pages/sharepoint2013-people-tracker-google-map.aspx>

(including pre-programmed messages) with a base (such as a parent's smartphone).

In addition to the technological issues, the tracking and identification of people also raise many questions and concerns pertaining to legal, ethical, moral, privacy, security as well as health and safety issues. In addition, employers thinking of using these systems will also need to be mindful of behavioural issues, such as resistance to change or privacy concerns, which may influence the successful adoption and implementation of the technology in a company.

Many products are aimed at the tracking and identification of assets. An interesting development is Delta Airlines' recent introduction of RFID-tagged baggage tags. It is claimed that this will significantly enhance the airline's luggage handling logistics, decrease misplaced and lost luggage and also offer customers the ability to track their luggage via an app on their own smartphones.

There are many opportunities for the development of new solutions and products to track and identify people, animals and assets. Whilst many applications will continue to utilise established technologies (such as RFID, GPS and Bluetooth), the continuous advances and improvements to these technologies offer many opportunities. There are also a number of emerging technologies which show great potential, particularly for niche and specialised applications.

One of the most exciting sources of opportunities will be the application of other emerging technologies such as the Internet of Things (IoT), 3D printing, drones, robotics and artificial intelligence, to tracking and identification problems. This includes applications in hazardous industrial settings. Recent **DeltaHedron Innovation Insight**⁹⁵ reports investigated developments in emerging digital health technologies and the impact of emerging technologies on the insurance

industry. In both cases, to name but two examples, there are many innovations which can also be applied to the tracking and identification of people, animals and assets, leading to products and solutions with greatly enhanced benefits and abilities.

Does your company have an innovation strategy – and if so, can you describe it and determine whether it is working? If not, do you sometimes find yourself wondering what happened... not even to speak of what can happen and which interventions should be made to shape the future?

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“There are three types of people in life – those who make things happen, those who watch things happen and those who wondered what happened...”

⁹⁵ www.deltahedron.co.uk/publications/



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Previous editions of *DeltaHedron Innovation Insight*

- [Developments in emerging digital health technologies](#), No 1.2/17, April 2017
- [The impact of emerging technologies on the insurance industry](#), No 2/17, April 2017



DeltaHedron Ltd is a UK-based business consulting company specialising in the management of technological innovation. We support our clients with the development and implementation of innovation strategies, and in assessing and capturing the strategic business opportunities and mitigating the risks and threats presented by emerging technologies and the dynamics of technological change.

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