Wireless location tracking sensors in Industry 4.0

-extended edition-

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Abstract

The literature review evaluates the most common standards of sensors and techniques that can be used for wireless location tracking in an Industry 4.0 organisation. It was found that tracking via radio waves is most common, they can be distinguished in dynamic systems that use triangulation (WLAN 802.11 and ZigBee), with a new development of fingerprinting, and stationary systems like near field communication (NFC) which is relying only on middleware and transmitter location.
Opportunities are highly customized products, Augmented Reality and customer insight, while challenges are not only data security and privacy. Further, an organisation must review if a valid and (financially) feasible business case can be created and with what choice of technology.

Contents

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The word count excludes the following:

- Cover page
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- Diagrams and sub text
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- Appendices

1. Opportunities with wireless location tracking

In 2017, cutting machine manufacturer Lectra launched several “Industry 4.0” services to their customers, allowing them to react to increasingly quicker requests of new designs (HARARI, 2018) or highly customized gear like athletic footwear (THOMAS REUTER ONE, 2017). The Industry 4.0 term was coined in the recent years (see Appendix A2 for details), forecasting a more connected, flexible and transparent production of goods and services using information technology (IT).

It can be considered worth tracking: First, the resource itself for a production process, allowing cloud controlled systems or local middleware to allocate the workpiece, enabling the business to move a workpiece through the manufacturing with individualized work orders, while at the same time doing stock-keeping and probably showing the customer where his product is.

Secondly, as part of Augmented Reality, which will require accurate tracking of the personal using it, to overlay the reality with enriched content based on the organisations databases, like with Google glass (Pierdicca, Frontoni, Pollini, Trani, & Verdini, 2017).

Finally, people working in Industry 4.0 may require location tracking, due to the requirement of more flexible working times and changing places (Hecklau, Galeitzke, Flachs, & Kohl, 2016). Location tracking of people could be associated with business work flows, allowing the IT systems to track that and for how long a work piece is worked on. In hazardous or risky environments like mines, tracking can avoid accidents (Hedley & Gipps, 2013).

The bridge between IT-based business processes and resources or people are defined as Cyber-Physical system (CPS), which allows to interact with each other, for example via sensors or tablets, which are mostly part of an IOT device (Obitko & Jirkovský, 2015). There are several technical feasible options for measuring, their choice is depending on the business case and purposed environment setup. The two most common systems found are RFID and WLAN/WSN based systems which the upcoming chapters will review and highlight strength and weaknesses.

2. Sensors for position tracking

a) Basics on sensor theory

With sensors, there is the measurand, *what* is being measured, and the transductor, the device capturing the measured data and allowing data processing (Kalantar-zadeh, 2013). In this document, the ultimate measurand is the location of the tracked item in question, the intermitted measurand in tracking with wireless devices is mostly based on signal strength or an identification number.

Base of all these technologies is the approach in IT to replace wires (Yang, 2014) and allow wireless data transmissions. See figure F.2a.1 for an overview of the current standards and their most common usage grouped by distance.

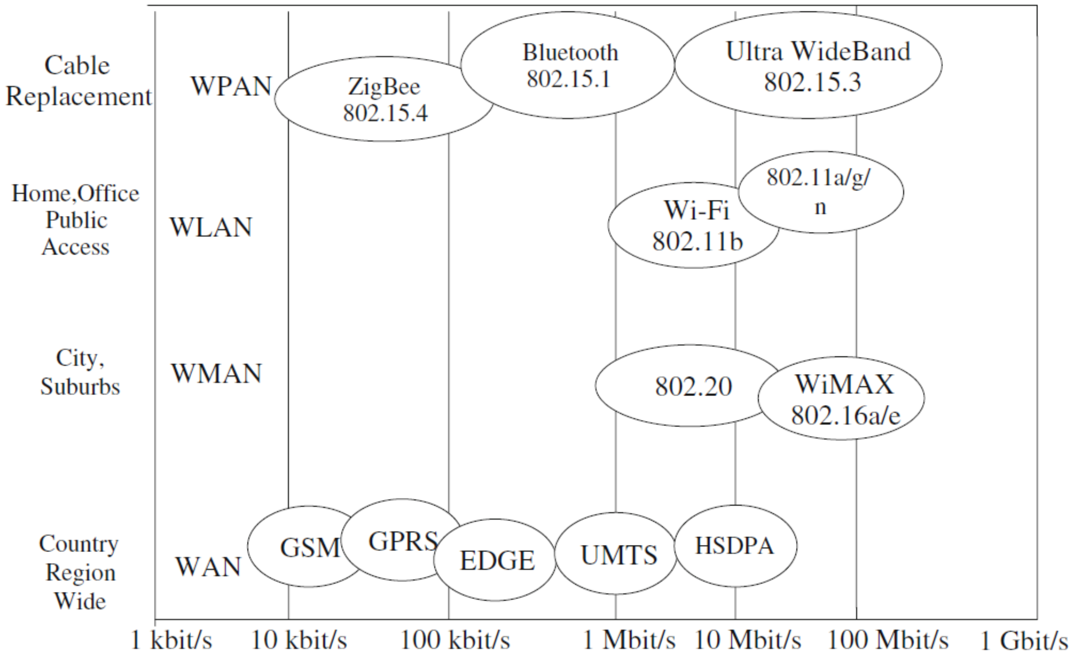

Figure F.2a.1: Overview of most common wireless networks
Source: Adapted from S.-H. Yang, Wireless Sensor Networks - Signals and Communication Technology, London: Springer-Verlag, 2014, figure 1.1, p. 2

The distance that signals can travel are highly bound to the frequency (and typical blockage) and power consumption. Figure F.2a.2 shows the wavelength spectrum and highlights the radio waves spectrum. The standard 802.11b Wi-Fi is at 2.4 Giga Hertz (GHZ) (Yang, 2014), while indoor radar tracking operates usually above 24GHZ (Tang & Li, 2014) and the Nearfield communication (NFC) group of Radio-frequency identification (RFID) of the HF class operates at only 13.56Mega Hertz (MHZ).

As radio wave, like all electrical waves, travels with the speed of light ($c = 3*10^8$ m/s), their frequency (f) dictates the wavelength (λ) give the formula:

$$\lambda = \frac{c}{f}$$

This does mean radio waves with a higher frequency have a very short-wave length, which is blocked quicker than low frequency / long-wave length, for example, 99,9MHZ (a FM radio frequency) (Lehpamer, 2012).

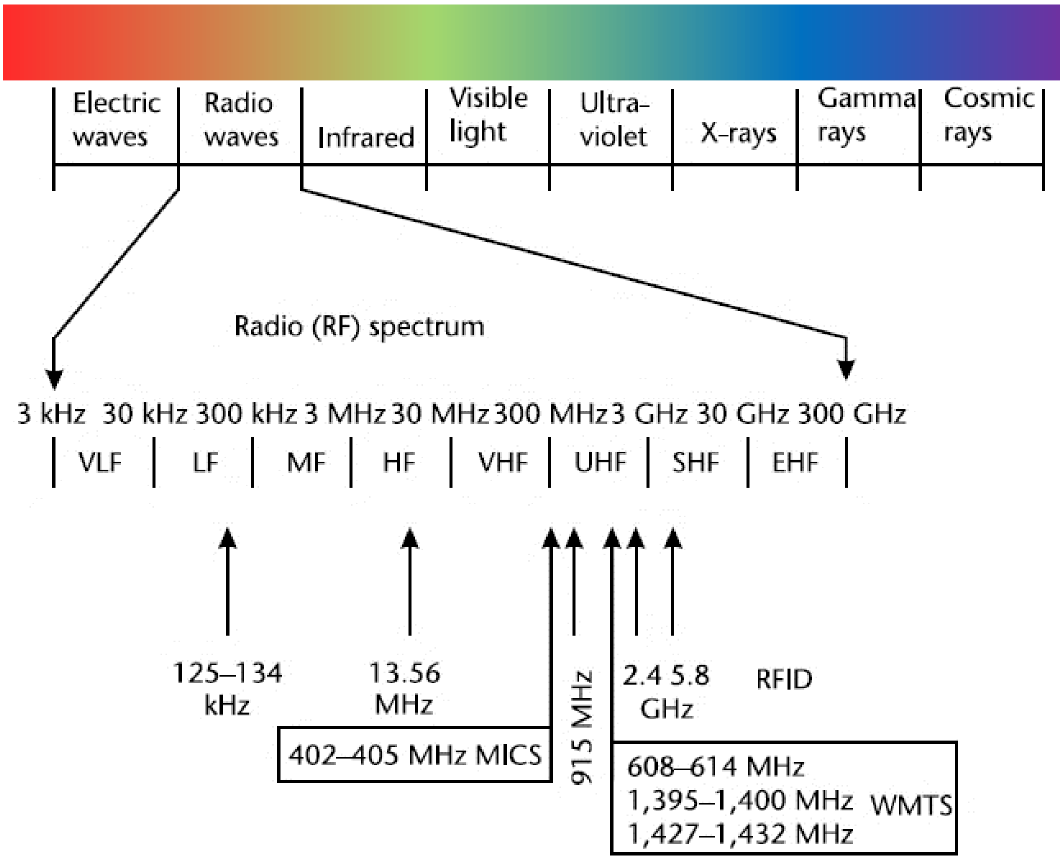

Figure F.2a.2 Electromagnetic radio wave spectrum as part of the overall wave spectrum
Source: Adapted from Lehpamer, H., RFID design principles (Second ed.), Norwood: Artech House, 2012, figure 2.2, p. 7

This should be carefully reviewed when an organisation is choosing the technology for location tracking, considering the surrounding factors of the installation like building materials or room dimensions.

b) Wireless technologies

As shown above, there are numerous ways of wireless data transmission, and all of them allow, to some extent, to use it for location tracking of the client. The (visible) light spectrum could be used for location measurements, but due to the cost of the optics and the constant readjustments of those for a moving target, it is more often applied in stationary measurements, like for quality purposes (Ross, 2013). Also, the GPS tracking is not suitable for indoor tracking, given that the client must have a clear line of sight (LOS) of at least three satellites for accuracy.

Other popular technologies not mentioned here are radar, which needs precise timing and complex mathematical formulas for triangulation of the time difference (Lehpamer, 2012) or Bluetooth low Energy (BLE), archiving tracking signal strength (Park a, Chen b, & Cho, 2017).

The upcoming section will review common radio waves technologies, also referred to as the radio frequency identification (RFID) when being used for identification.

I. WLAN 802.11

The wireless network that an organisation has put in place for data communication, can be used for location tracking. Memory producer Hynix did so in 2005 (PR NEWSWIRE EUROPE, 2005), with the real-time location systems (RTLS), using the 802.11 Wireless access points (AP) for tracking of material and staff, who have wireless hardware.

Figure F.2bI.1 shows that RTLS uses the measured distances (di1, di2, di3) to the sender (Wireless APs), by means like signal strength, to triangulate the location of the target relatively to the three transmitters. RTLS was prepared with the location data of all the transmitters (APs), and the combined outcome is the location of the target. 802.11 operates at 2,4 or 5GHZ, providing ranges of up to 70 meters and 1,3GBit/s (802.11*ac*). Existing wireless data network covering the organisation's premises, allow for quick enablement of location tracking. Target chips are medium costly as they need to be active.

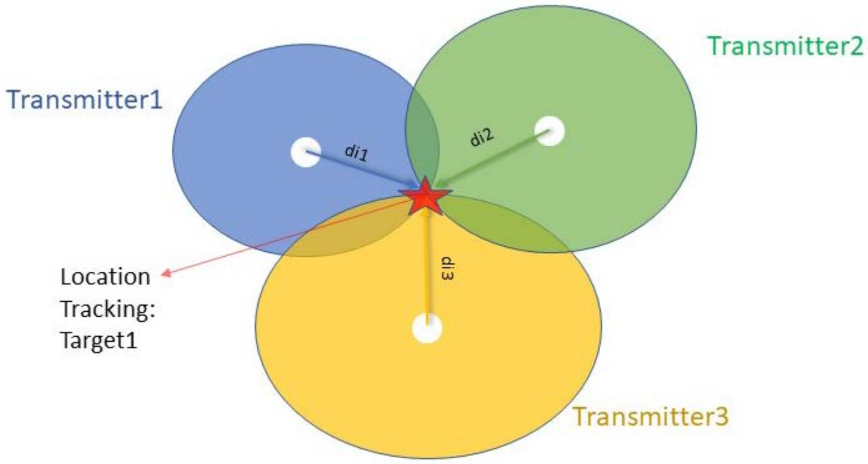

Figure F.2bI.1: Wireless Triangulation for location purposes.
Source: Author

II. ZigBee

The ZigBee Protocol operates on 2.4 GHz, but also on 868 MHz in Europe, the latter can provide better penetration through walls and alike, has lower power consumption and hardware cost is low (Yang, 2014). However, both versions do not offer high data rates (max 250kbit/s) (Yang, 2014) with up to 20m indoor range. Two changes to 802.11: First, there must be a main transmitter with a connection to a middleware software, called Coordinator and secondly, the other transmitters (called routers) can natively relay their data packages to each other, called *peer-to-peer*, they do not need a wired connection, see figure F.2bII.1. These networks are called Wireless Sensor Networks (WSN) (De Sales Bezerra, De Sousa, Da Silva Eleuterio, & Rocha, 2015).

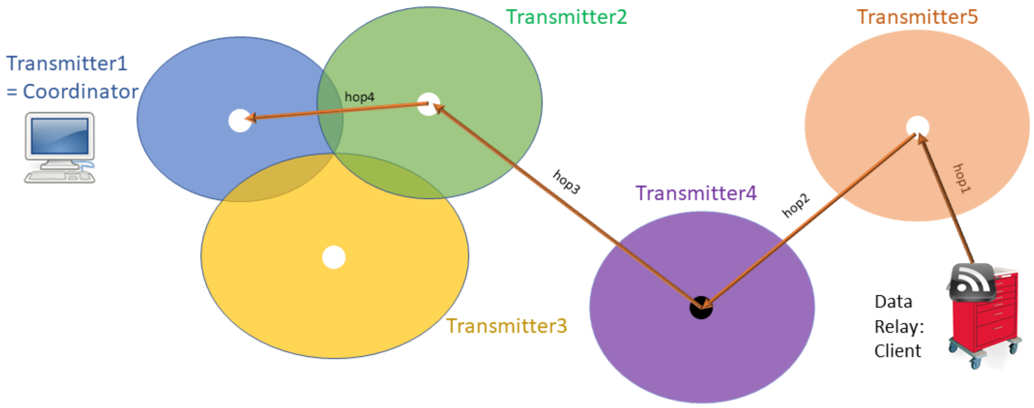

Figure F.2bII.1: ZigBee Data Transmission via relaying messages - "peer-to-peer".

Source: Author

Using, for example, signal strength for location triangulation, see figure F.2a.2, again the transmitter locations must be put into a RTLS system to combine both values and calculate the current location of the client.

Another method of location tracking is fingerprinting, which can also be used in 802.11 WLAN (Swangmuang & Krishnamurthy, 2008). During the offline phase, see figure F.2bII.2, a target-simulator scans and walks through the area of interest and maps reference locations on a grid. On each location, the specific signal strength will be and stored as a fingerprint in a large database. In the online phase, targets submit their signal strength and the central system looks the closest value up in its database, and assign it the defined location for this "fingerprint". This reduces power consumption in comparison to 802.11 mapping. (Niu, Wang, Shu, Duong, & Chen, 2015).

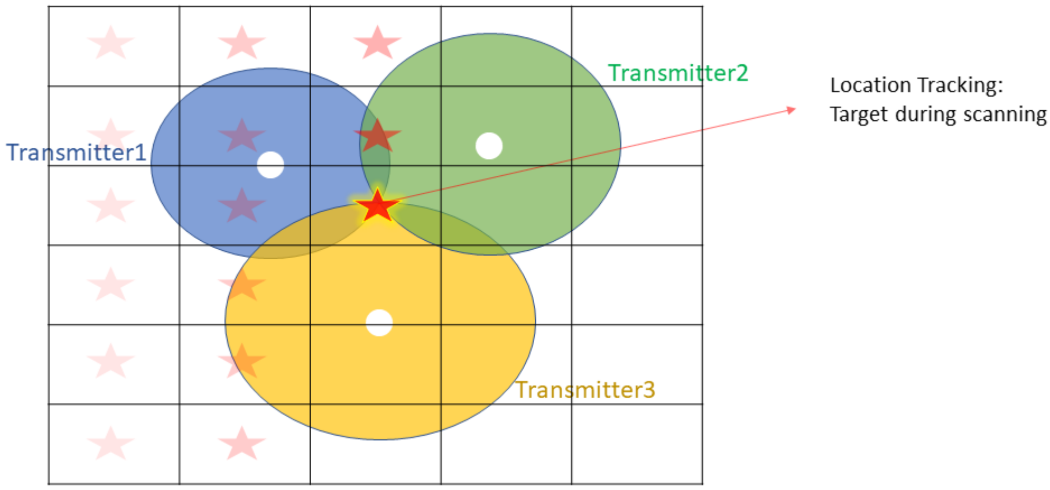

Figure F.2bII.2: Wireless fingerprinting in process.
Source: Author

ZigBee Clients only require power when sending actively and can have large sleep times, allowing for further low power consumption (Yang, 2014), which is especially important if the environment needs to restraint power usage during operating times.

The hardware cost is low (Yang, 2014) if there is no existing network and no data or only low data bandwidth is required. Further, only power is required for the routers: costs for network cable, installation, network hardware can be saved. This allows the network to be installed or moved quickly and with low effort, example given in case of an emergency. This network is most widely spread in Building Management and Home automation (Yang, 2014), where low data rates with good energy management and signal penetration is key.

III. Near-field communication (NFC)

The Near-field communication (NFC) is used to track and identify material and persons (Lehpamer, 2012). It is predicted that by 2018 over ⅔ of all mobiles do come with a built-in NFC, creating vast possibilities for customers and staff tracking (NFCworld, 2014). NFC clients are referred to as *tags* or transponders, with antennas being the size of a stamp (Product News Network, 2010) or even less, they can track nearly everything that needs tracking or identification. The upside of NFC is the versatility and the interaction of NFC tags, as the tags do come with a chip that can store data up to 4Kbyte. The transmitter (called interrogator/reader in NFC) needs to supply power to the passive tag to receive information stored on it, like serial number, or workpiece instructions. This data is passed on from the transmitter to an RFID middleware, connection back into the business process setup and deciding on the next step.

For location tracking, the RFID middleware will have a location database per transmitter, like the fingerprint described earlier, and know the tracked item is in reach or has passed that transmitter. Based on the received data the middleware can then decide and initiate the next step in the value creating or business process.

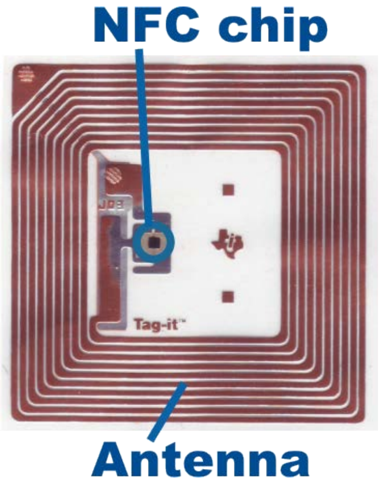

Illustration I.2bIII.1: Innerworkings of a NFC chip.
Source: Bonwal: http://www.bonwal.fi/en/nfc-tags

NFC, see Illustration I.2bIII.1, is on the mid frequency (13,56MHZ), low price (0,08 € for large volume), low power (passive), and very low distance (a few cm up to 5m) side of the RFID solutions (with active solutions spanning up to 100m). But with billions of tags applied per year it's very popular, with a price point that makes it easy to be disposable after use (like tracking).

Most big banks have started to incorporate the NFC chips in their credit cards, allowing contactless payment, for example Amex, MasterCard, Maestro, Visa can be used for paying contactless for traveling through London via Bus or Tube (TFL, 2018). Banks and Transportation companies can ultimately save the individual cards and allow the use of the mobile NFC chips.

Supermarkets can enable loyalty cards and move their customer tracking to NFC, allowing for further big data processes like data mining as well as saving money on the plastic card (Voges, 2017).

In logistical tracking, it can be archived that stock checking and inventory can be completely automated, reducing time for manual inventory and revisions (Lehpamer, 2012).

As mentioned in chapter 1, a business process could be built around a work piece, like a car, where the customer can individualize it to a large extend, and this individualisation can be stored on the NFC tag. When the work piece is starting its journey in the company's value chain, all stations can pick up this data from the tag or dynamically receive it via the RFID middleware and feedback the status to manufacturing managers or customers in the process. The result would be a cyber manufacture (Lee, Bagheri, & Jin, 2016).

3. Challenges

a) Technical challenges

The wireless aspect of tracking comes with the two main technical challenges for wireless itself: Interference and obstacles. The first occurs when the radio waves overlap and cause them to be not readable by the transmitter, which will increase with more clients using the same frequencies. Further Interference can be caused by *Incidental radiators*, electrical devices like an old electrical motor that is not properly shielded (Lehpamer, 2012). The latter can be the building itself or moving parts in the transmitter area that either reduce or reflect the signal (causing interference). Both effects can induce variances in the signal strength and hence the calculated location. Good planning of the area that will be used for wireless, for example via a building information model (BIM) can reduce such impairments (Park a, Chen b, & Cho, 2017).

As the target is mobile, we must assume it is battery powered (if not passive like NFC) and has limited energy resource, (like a Laptop) so the clients need to have good energy management for any location tracking actions and operation time of an individual client needs pauses to recharge the battery.

b) Business case and value chain modification

The word ubiquitous is use very often in the combination with IT and wireless, yielding 735804 search results on the University of Salford library search engine. The concept called ubiquitous (meaning “that is everywhere”) was introduced by Xerox’s PARC (Palo Alto Research Center) in 1988 for the first time. However, often business premises have no full coverage of a wireless network due to cost and return of invest calculations. Within established businesses, they may have not found the need or upside of using any wireless tracking technology, making it hard to see why to invest (Lee, Bagheri, & Jin, 2016). When the business has decided to setup wireless tracking for a process in the value chain, planning (like BIM) will be important, but also the suggested transmitter density required and the resulting accuracy (as the difference use cases have varying requirements) needs to be calculated, otherwise it could be found that the project would be excessively expensive with no return of invest or just unfeasible.

Further, any organisation needs to build big data use cases, what to do with the data collected. Will the time a customer spends in front of a specific shelve be impacting what will be stored next to it; How will total store time / on premise time be used?

Recently the trend is to use more than just one system for location tracking, assumptions are that by 2021 over 65% of enterprise tracking will use more than three technologies (Gartner, 2018). All RFID technologies from chapter 2b can be extended with accelerators sensors, allowing to use the second sensor via, for example Kalman filter calculations to remove outliers (Chai, et al., 2017).

Any organisation should consider building big data use cases.

c) Security

RFID tags were built with security in mind, for example their serial number is also their MAC address, which can only be written with factory equipment, setting a high hurdle for scammers (Lehpamer, 2012). Security of any data must be guaranteed, during the three states: while in transit (encryption of location data), securely transported (via wide or local area networks) and stored in the middleware or could backend systems, with access only to authorized personal (Lehpamer, 2012).

To guarantee data integrity, a Blockchain mechanism could be used for security, mapping the location data for one client in a tamper-proof database (Tackmann, 2017).

The air in which communication is taking place is a shared medium, which can be impacted by intentional denial-of-service (DoS) attacks like *jamming* or undeliberate misuse or overloading by use of others stopping communication, even if these factors causing distortion are not on premise. Where the value chain is relying on wireless location tracking, safety measures (physical wireless shielding from outside and software detection/blocks of attacks (Huang, Liao, Chung, & Chen, 2013)) and contingency plans for a foreseeable downtime should be put in place and tested regularly, which are vital in a medical environment (Larsen, Haubitz, Wernz, & Ratwani, 2016).

d) Privacy and the law

Failure to build public trust in data security, like the current Facebook debate (Yadav, 2018), is building up resistance to adapt new technology, including wireless tracking like NFC, and slowing down the dissolution more than objectively suggested, when the customer does not accept or use these as he could (Voges, 2017).

Building trust is one of the key points when working with customers, but also with staff; a few key words that need to be honoured are honesty, predictability, fairness and openness (Ebert, 2009).

With this and ethical standards in mind, when people (customer or staff) are tracked, they should be informed about it and allowed to “opt out” of such tracking where technically feasible to establish a sustainability relations ship with either high workforce moral (see Illustration I.3C.1) or satisfied customers. As technology has no moral, the operator needs to ensure the encoded processes is reflecting the ethical standards of the society the technology will be used in (Lehpamer, 2012).

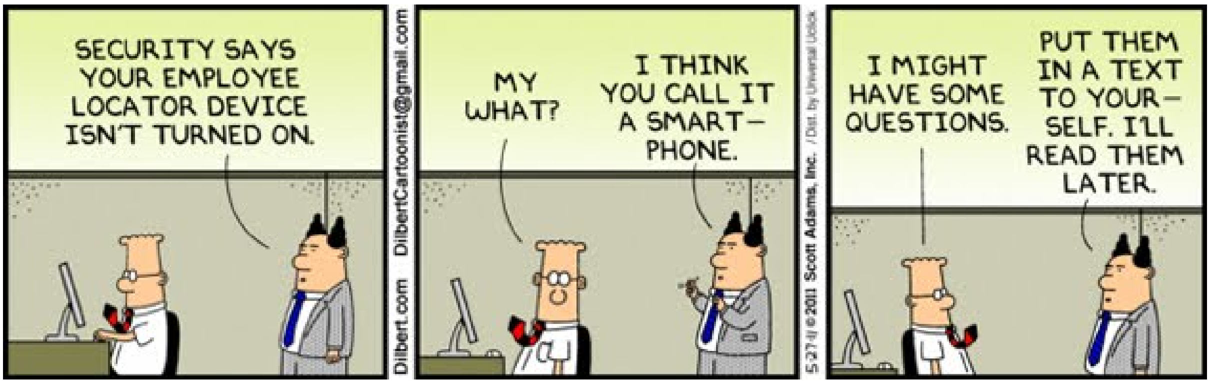

Illustration I.3C.1 – Privacy concerns with employee tracking.
Source: Canadian Privacy Law Blog, March 16, 2018, Posted by David Fraser, URL: http://blog.privacylawyer.ca/2011/07/dilbert-employee-locator-device.html

As technology has no moral, organisations need to ensure the encoded processes are reflecting the ethical standards of the society the technology will be used in (Lehpamer, 2012).

While some project suggest that child tracking is of the benefit of a child (Kamaludin, Omar, Sabapathy, Iskandar, & Kamarudin, 2017), ethical concerns are wide spread that this privacy breach confusing control with care. Among the concerns are the increased discomfort, reducing autonomy and self-reliance while constantly creating fear on both sides that something bad could happen (Gabriels, 2016).

Where an organisation's ethical board or CEO decide not to care about trust, the applicable law must be abided. EU does dictate General Data Protection Regulation (GDPR) with a *Privacy by Design and Privacy by Default* clause, allowing anonymous use of any service, but with the large amount of data that can be tracked back to one person by using a IOT or mobile devices, it is mandatory to rethink how to programme. (Voigt & von dem Bussche, 2017).

Wireless location tracking
in Industry 4.0

Opportunities

In 2017 Lectra launched several "Industry 4.0" services to their customers, allowing them to react to increasingly quicker requests of new designs[01] or highly customized gear like athletic footwear. The Industry 4.0 (I4.0) term was coined in the recent years (see NFC Tag lower right for details), forecasting a more connected, flexible and transparent production of goods and services using information technology (IT). In I4.0 there are the following opportunities for tracking: First, the resource itself for a production process, allowing middleware to allocate the workpiece, enabling the business to move a workpiece through the manufacturing with individualized work orders, while doing stock-keeping and probably showing the customer where his product is. Secondly, as part of Augmented Reality, which will require accurate tracking of the personal using it, to overlay the reality with enriched content based on the organisations databases[18]. Finally, people working in I4.0 may require location tracking, due to the requested of more flexible working times and changing places[02]. Location tracking of people could be associated with business work flows, allowing the IT systems to track that and for how long a work piece is worked on. In hazardous or risky environments like mines, tracking can avoid accidents[03].

Sensors & Waves

With sensors, there is the measurand (*what*) and the transductor (*how*) allowing data processing[04]. Here, the ultimate measurand is the location of a tracked item, the intermitted measurand in tracking with wireless devices is mostly based on signal strength or an identification number. Base of these technologies is the approach in IT to replace wires[05] and allow wireless data transmissions. Signal distance are bound to the frequency and their typical blockage. Figure F.2a.2 shows the wavelength spectrum and highlights the radio waves. Waves with a higher frequency have a very short-wave length, usually blocked quicker than low frequency and long-wave length[06]. Organisation need to carefully when choosing a technology for location tracking, considering the surrounding factors like building materials or room dimensions.

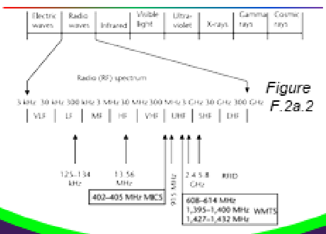

Figure F.2a.2

Wireless technologies

Wireless data transmission techniques allow, to some extent, to be used for location tracking. GPS tracking is not suitable for indoor tracking, given that the client must have a clear line of sight to satellites.

WLAN 802.11

The wireless network that an organisation has put in place for data communication, can be used for location tracking. Memory producer Hynix did so in 2005[08], with the real-time location systems (RTLS), using the 802.11 wireless network for tracking of material and staff. Figure F.2bI.1 shows that RTLS uses the measured distances (di1, di2, di3) to the transmitter, by means like signal strength, to triangulate the location of the target relatively to the three transmitters. RTLS was prepared with the location data of all the transmitters, and the combine outcome is the location of the target. 802.11 operates at 2,4 or 5GHZ, providing ranges of up to 70 meters and 1,3GBit/s.

The **ZigBee** Protocol operates on 2.4 GHz and 868 MHz (Europe) the latter provides good penetration through walls and alike, has lower power consumption and hardware cost is low[05]. Two changes to 802.11: There must be a main transmitter with a connection to a middleware software, called Coordinator. Secondly, other transmitters (called routers) can natively relay data packages, called *peer-to-peer*, they do not need a wired connection, see figure F.2bII.1. These networks are called Wireless Sensor Networks (WSN)[09]. Again, Signal Strength and RTLS is used for location tracking. Another method is *fingerprinting*, which can also be used in 802.11 WLAN[10]. During an offline phase, see figure F.2bII.2, a target-simulator scans and walks through the area of interest and maps reference locations on a grid. On each location, the specific signal strength will be and stored as a *fingerprint* in a large database. In the online phase, targets submit their signal strength and the central system looks the closest value up in its database, and assign it the pre-defined location for this *fingerprint*. Maximal speed is 250kbit/s at an indoor range of 20m.

Near-field communication (NFC) clients are referred to as tags which are very cheap and can store data. The transmitter needs to supply power to the passive tag to exchange information. This data is passed to a middleware, deciding on the next step of the business process. For location tracking, the middleware will have a location per transmitter and know where the item is, based on the received data the middleware can then decide and initiate the next step. NFC is usually on frequency (13,56MHZ), has a low price, no power consumption, and very low distance (10 cm) and billions of tags are applied each year[15].

Challenges

Main **technical challenges** are interference and obstacles causing radio waves not to be read correctly by the transmitter, induce variances in the signal and calculated location. Good planning of the area that will be used for wireless, for example via a building information model (BIM) can reduce such impairments[11].

Business case and value chain modification: Often organisation's premises have no full coverage of any wireless network due to costs calculations. Established businesses may not have found the need of using any wireless tracking technology, seeing no reason why to invest[12]. When the business has decided to setup wireless tracking for a process in the value chain, planning (like BIM) will be important, to estimate the transmitter density and the resulting accuracy required for the use case. It could be found that the project would be excessively expensive with no return of invest.

Security: For NFC tags, their serial number is their MAC address, which can only be written with factory equipment, setting a high hurdle for scammers[06]. Wireless communication can be impacted by intentional denial-of-service (DoS) attacks like jamming, undeliberate misuse or overloading by use of others stopping communication. Where an organisation is relying on wireless location tracking, safety measures like physical shielding and contingency plans for a downtime should be put in place and tested regularly[13]. Security of any data must be guaranteed during the three states: while in transit and when stored in the middleware, with access only to authorized personal [06].

Privacy & Law: Loss of trust in data security, like the current Facebook debate[14], is building up resistance to adapt new technology like NFC[15]. Building trust is one of the key points when working with customers, but also with staff. Key words for ethical standards are honesty, predictability, fairness and openness[16]. So when people are tracked, they should be informed about it and allowed to "opt-out" of such tracking to establish a sustainability relationship with either high workforce moral or satisfied customers. As technology has no moral, organisations need to ensure the encoded processes are reflecting the ethical standards of the society the technology will be used in[06]. Organisations must be abided the applicable law: EU does dictate General Data Protection Regulation (GDPR) with a Privacy by Design and Privacy by Default clause, allowing anonymous use of any service, but with the large amount of data that can be tracked back to one person by using a IOT or mobile devices, it is mandatory to rethink how to programme [17].

Conclusion

Existing wireless **data network** covering the organisation's premises, allow for quick enablement of location tracking. **ZigBee** hardware cost is low[05] if there is no existing network and only low data bandwidth is required. Only routers require power, only coordinators middleware connections, costs for network cable, installation, network hardware can be saved, this allows the network to be installed or moved quickly and with low effort.

Loyalty cards can move their tracking to **NFC**, allowing for further big data processes like data mining as well as saving money on the plastic card, when using the banks NFC chip[15].

Any organisation should consider building **big data use cases**, but needs to ensure **data security and privacy** to maintain trust of customers and staff.

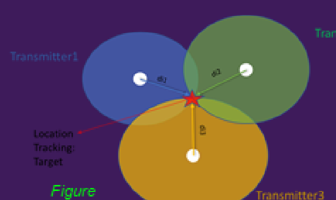

Figure F.2bI.1

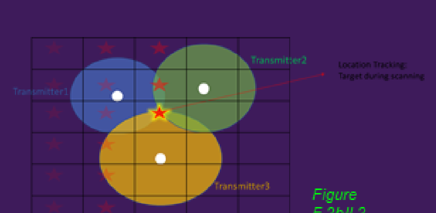

Figure F.2bII.2

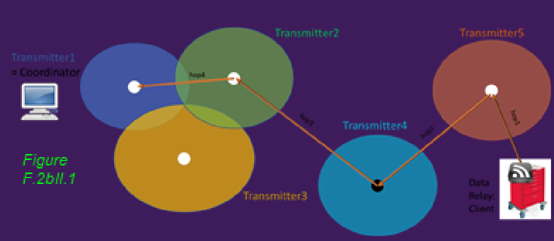

Figure F.2bII.1

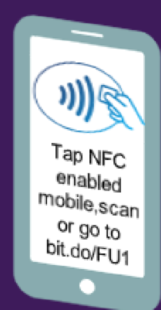

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Figure F.2a.2 Source: Adapted from Lehpamer, H., RFID design principles (Second ed.), Norwood: Artech House, 2012, figure 2.2, p. 7 ; Figure F.2bI.1, F.2bII.1, *F.*2bII.2 Source: Author (Frederik Unser)

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6. Appendix A1: Reflecting on the creation process

Using the Gibb's reflection cycle for debriefing as show on www.salford.ac.uk/skills-for-learning/home/reading-and-writing#reflective and reviewed by Husebø, S.E., O'Regan S. & Nestel, D (2015) for use in the health sector.

Word Count: 325 (not counting Introduction and Reference)

a) Description

I am currently studying Information Technology Management at the Salford University, provided via Robert Kennedy College as a distance learning programme. As part of the study, the Digital Innovation course's mid-term assignment, I was asked to write a literature review about opportunities and challenges from the use of sensors (or a subset) for businesses. The literature review and the required poster are now completed as I write these words for the reflecting cycle.

b) Feelings

I was excited to get started on the technical areas of my study, combined with more time. This was damped when I received the marks from the earlier, very literature based, final assignment which came in much lower than the mid-term review.

c) Evaluation

At this time, I was on a vacation but had my learning materials with me, however I did not start to write (or read), despite having my target area for the literature review identified and a framework drafted. When starting the reading on sensors and their computerized usage, they reminded me of my A-Levels in physics which I liked. When writing about wireless I could find topics from my earlier and everyday connections like NFC in my own credit cards. After I was done with the literature review, I had too many words.

d) Analysis

Topics like detailed physical formulas, RADAR, child tracking and recap were removed to fit in the word count. This did result in extra work while removing topics that had already work effort in them, consuming time.

e) Conclusion

My conclusion: First there must be focus to use nearly all words for the assignment, even if subjectively more interesting topics are related to the given task are found. Secondly, my draft-structures of the assignment should be assigned a broken-down word count which should be checked regularly.

f) Action Plan

The next assignment, more regular checks must be done to ensure word count and topics are in line with the assignment.

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Husebø, S.E., O'Regan, S. & Nestel, D (2015). Reflective Practice and Its Role in Simulation. *Clinical Simulation in Nursing, Volume 11, Issue 8,* p. 368-375

7. A2: Industry 4.0

The Industrial development can be categorized in the four steps shown in figure F.A2.1

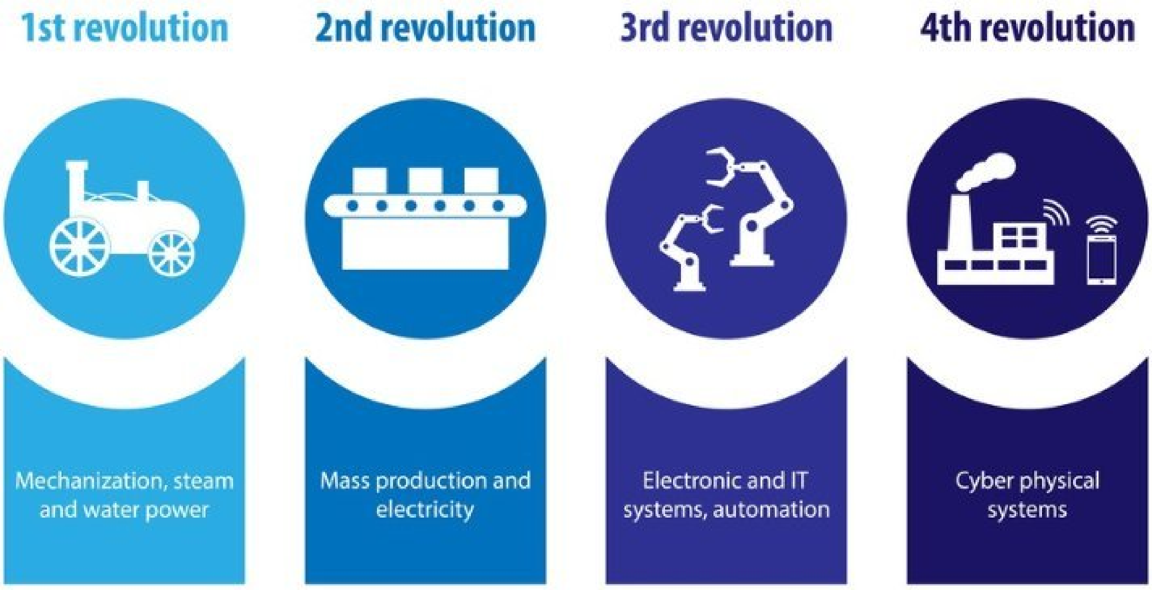

Figure F.A2.1: Characterization of the four industrial development steps up to 4th revolution. Source: Bill McCabe, IOT Central, Received from: https://www.iotcentral.io/blog/the-evolution-of-industry-4-0

In the first step, around 1784, there is the industrialisation that allowed for great production and a more efficient production than doing things "by hand", the second step is the mass production and the greater use and availability of electricity (Smith, 2014). In a third step, the use of IT systems and automation (the use of robots) moved into the manufacturing and any other industrial sector (Gill, 2013).

The fourth revolution "Industry 4.0" is a forecasted outlook from a German study started by the government and completed by several universities in 2013 (Bendel, 2018). In this, the new outlook of a customized product, based on the Big Data trends (Obitko & Jirkovský, 2015) and the IT-enabled hyper customisation (ACCENTURE, 2018), allowing (and setting the expectation of customers) to get a highly customized product. Opel/Vauxhalls offers to produce a car with your very own colour (Opel/Vauxhall, 2018) – not only, like Henry Ford said 1909 at the start of the second Revolution, "any colour so long as it is black".

This and the Lectra example from chapter 1 show that in the current and future industrial environment, IT-connected environments and customised products become more and more important and ultimately financially vital for many organisations (HSRC, 2018).

Out of the nine pillars of industry 4.0 (Laudante, 2017), the following would be mostly exposed to tracking: Autonomous robots (as receivers), the Industrial Internet of Things (IOT) (as infrastructure support), Additive manufacturing and Augmented Reality (as receivers) and to a remote extend the Cloud and big data, collecting and computing the data and being protected by (Cyber-) Security. Already, there may be partial appliance of these theories in some businesses today, like tracking your parcel online, but connecting all the business processes (including customer input) and value creation combined, is what is defining the new age of Industry 4.0.

The bridge between IT-based business processes and resources or people are defined as Cyber-Physical system (CPS), which allows to interact with each other, for example via sensors or tablets, which are mostly part of an IOT device (Obitko & Jirkovský, 2015). There are several technical feasible options for measuring, their choice is depending on the business case and purposed environment setup. The two most common systems found are RFID and WLAN/WSN based systems which the upcoming chapters will review and highlight strength and weaknesses.

One aspect of this will be the logistic and location tracking of the products, resources and visualisation of the environment. While there are macro locations, for example a city or manufacturing site, it may also be vital to the business to know where any individual and customized product is in such a site (micro location).

To do all this, without any additional waiting time or increase in price, organisations need to reorganise and integrate their value chain into systems that allow them to deliver seamlessly (Ustundag & Cevikcan, 2018).