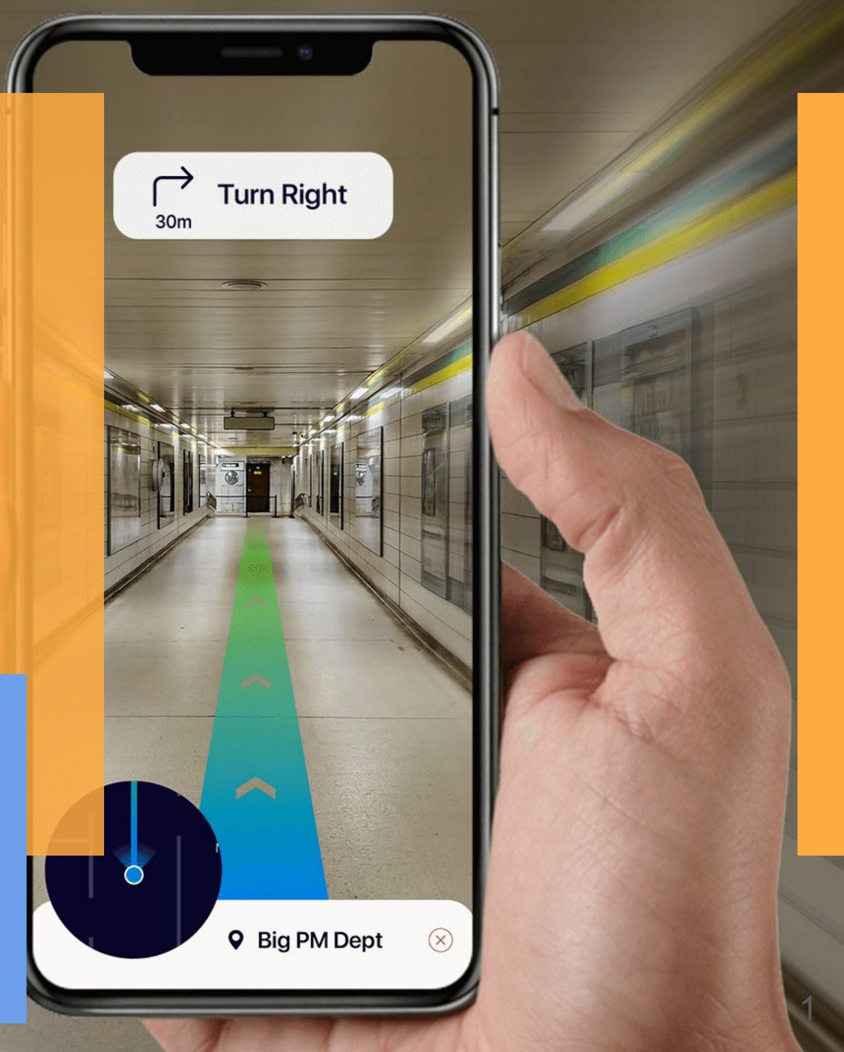
INDOOR NAVIGATION

Service for indoor navigation on forums and exhibitions



Technology Planning and Roadmapping
Final presentation

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Structure

1. Introduction

Background / Context

Objectives

2. Approach (How?)

3. Results

4. Validation

5. Conclusions & Lessons Learnt from TPR:F/TPR:A

6. References

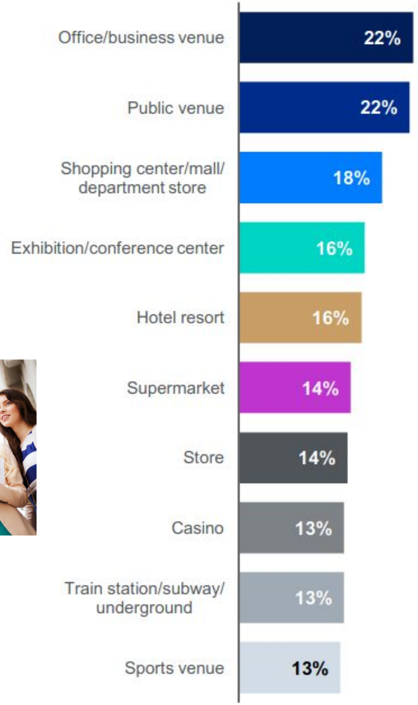
Background / Context

Indoor navigation solutions is a wide range of products and services. While "indoor routing" functionality that guides people through the buildings is important, there are lots of services which support it, such as content management system, mobile and web applications, indoor and outdoor localization, social networks, data analytics and many others.

Why do we need indoor navigation and positioning?

- Convenience of global Geo-services
- GPS reception problems inside buildings

One of understandable example of such kind of products is a Google Maps, which is scaled to work inside the buildings.



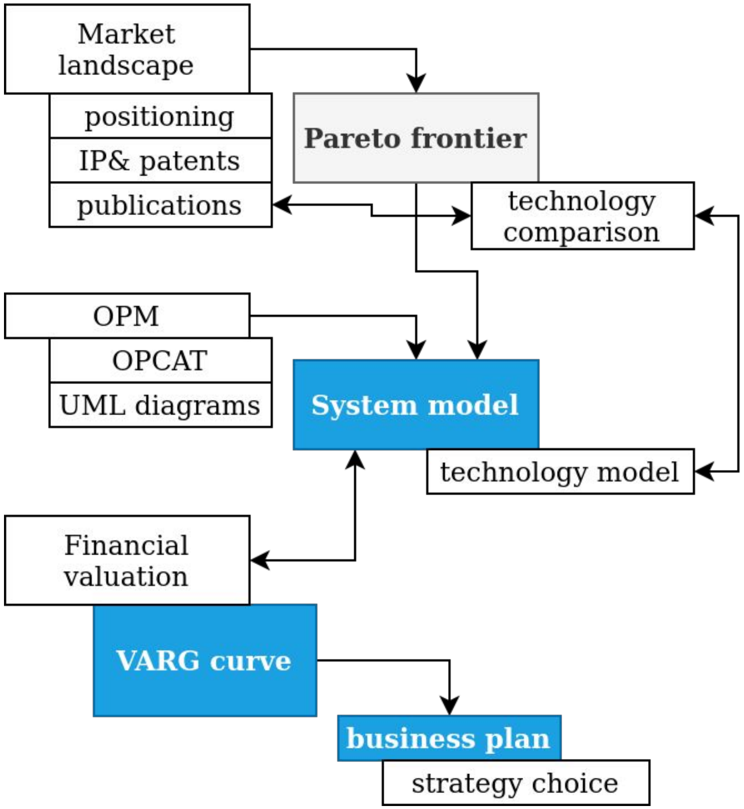
Infsoft, “Indoor positioning and services white paper,”2019.

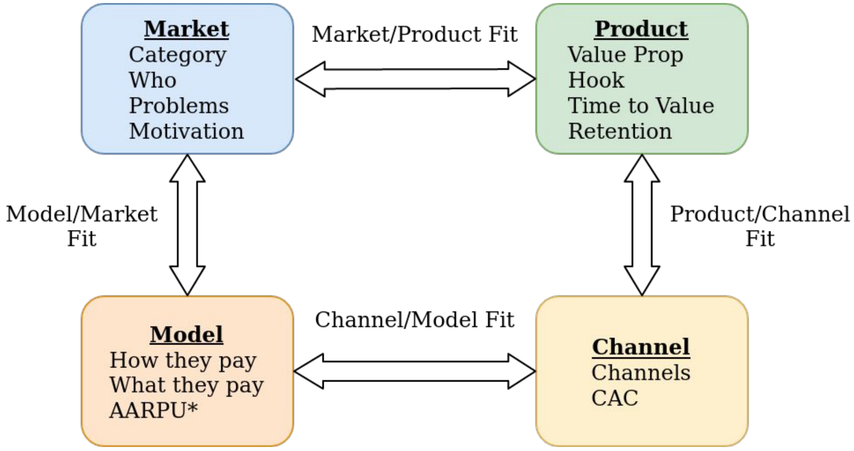
Objectives

There are several important points in this scientific area to assist in:

- Taking decision of technology / product choice
- Understanding physical limits with a feasible model of technology
- Understand Timeline and Market scenarios
- Landscape of technology with literature and patent review

Approach





- indoor, building
- positioning, localisation, tracking, location
- magnetic, fingerprint
- WiFi, RSSE, trilateration, iBeacon, RSSI
- BLE, Bluetooth
- no hardware, wireless
- accuracy, precision, latency, cost
- exhibition, shop, retail, customer

Figures of merit

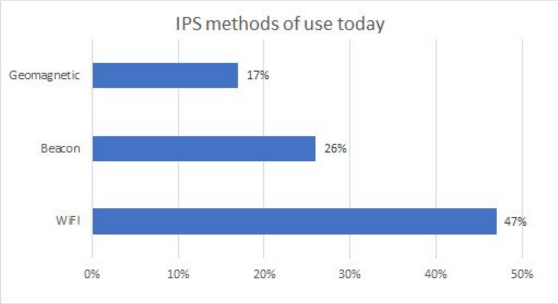
Technology FOM's

Figure of merit	Units	Description
cost hardware, software	f(USD/sqm)	cost or hardware rent to provide coverage of needed area with normal operating accuracy
accuracy	m	accuracy of localization, difference between real position and measurements
range	*m*	*Not important factor, complexity and scalability are affected by this factor. Not representative, because of different types of implementation. Excluded from FOM's*
additional requirements	*USD; year*	*If yes, product is not applicable until they are not solved. Not implemented into model, technologies with additional requirements are mot mapped. (Infrastructure Requirements, Impacts and Notes)*
Scalability	*low/med/high*	*range of scalability, important factor to consider in strategy choice*
Complexity	*low/med/high*	*range of complexity, important factor to consider in strategy choice*
Robustness		*additional information of what affect the performance of technology*

Product FOM's

Figure of merit	Units	Description
development time	month	time to develop the product based on technology with specified accuracy
accuracy	m	accuracy of localization, RMS error between real position and measurements

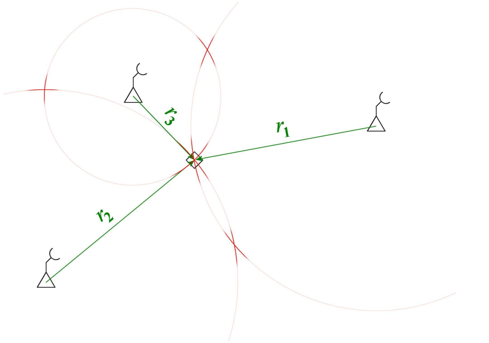
Technology comparison



IPS Technology	Accuracy, m	Scalability	Complexity	Type
Geomagnetic	2	Low	Low	fingerprinting
Photo	1-10	Low	High	camera
Barcodes	1-10	Medium	Low	camera
Video, AR	1-10	Low	High	camera
Bluetooth Low Energy (BLE)	1-3	High	Medium	Radio
RFID, Active	1-10	Medium	Medium	Radio
RFID, Passive	1-10	Medium	Medium	Radio
Wi-Fi	5-10	High	Medium	Radio
Ultra Wide Band (UWB)	0.15-0.5	Low	Medium	Radio
Zigbee	3-5	Low	Low	Radio
FM	2-4	Low	Low	
Lighting-Based – Infrared LED	0.15-3	Low	Low	Lighting
Lighting-Based – Visible LED	0.3-3	Low	Low	Lighting
Audible	0.5	Low	Low	sonic
Ultrasound	0.05-0.25	Low	Medium	sonic
Inertial		Low	Low	supplementary
Pressure				supplementary
GPS	6-10	Low	High	supplementary

Technological limits

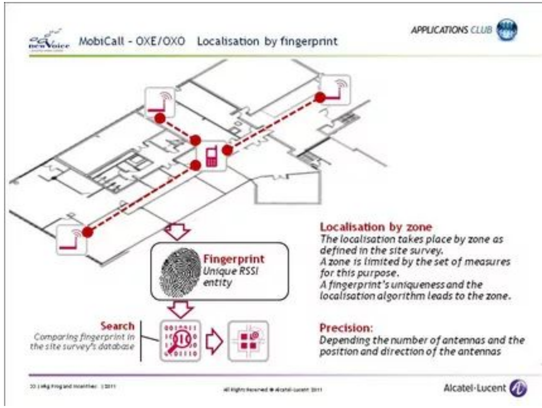
3 types: radio *(distance)*, image *(angle)*, fingerprinting *(position)*



Radio (multilateration, distance measurement), fingerprinting: noise level, wave reflections, sensor errors are main limitations.

Because of noise, the technology limit can't be reached, only on frequencies where is no external noise, wave reflections - scanning error depends on geometry of signal way.

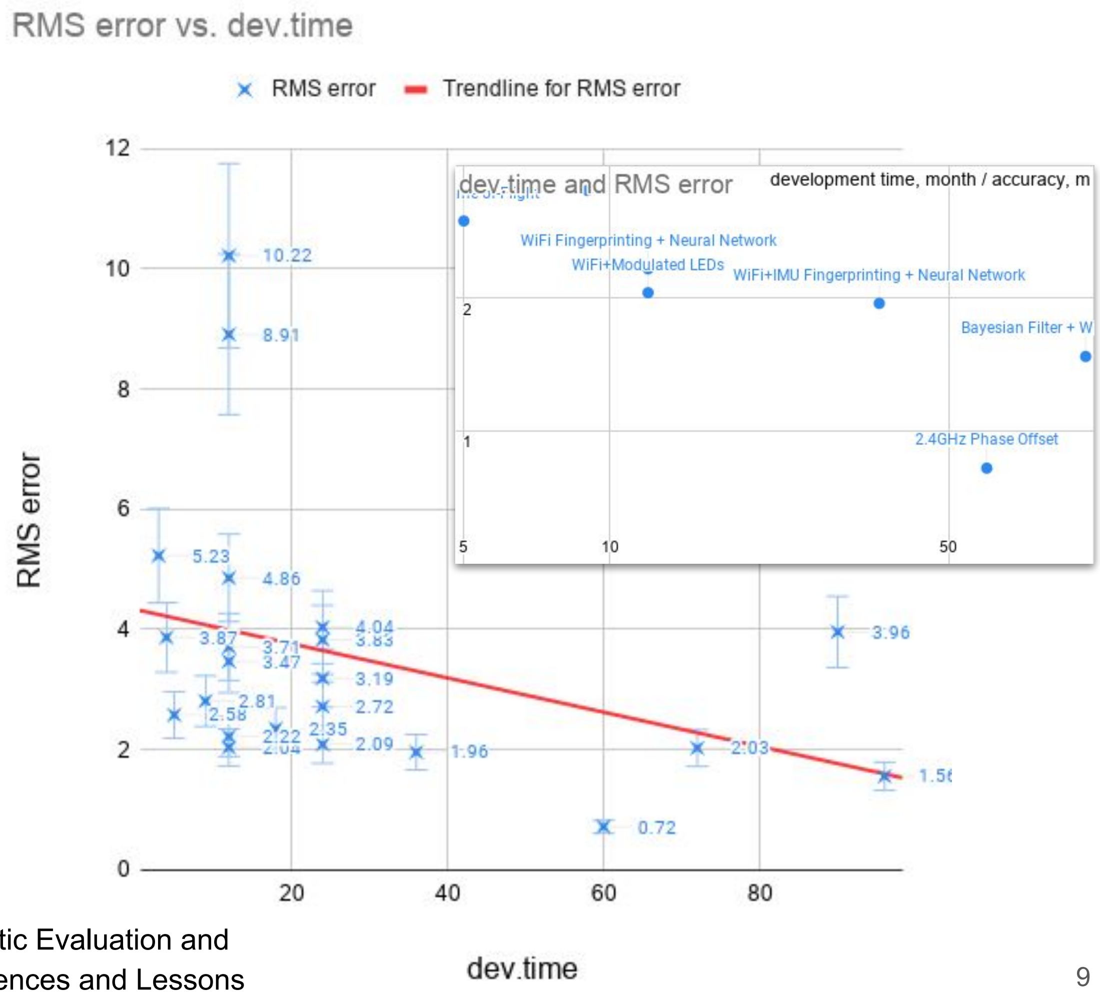
Image based: accuracy/precision of localisation depends on camera angle resolution. Because trilateration with camera is not possible, error is a linear function of range.



Alcatel-lucent 2011 localisation by fingerprinting

Technology comparison

Technical Approach	Dev.time, month	RMS error, m
2.4GHz Phase Offset	60	0.72
WiFi+Modulated LEDs	12	2.04
2.4GHz Time-of-Flight	72	2.03
Ultrasonic Time-of-Flight	24	2.09
IR/Radio Time-of-Flight	18	2.35
2.4GHz Time-of-Flight	5	2.58
WiFi+Bluetooth+IMU	24	2.72
Modulated Magnetic Signals	24	3.83
SDR Time-of-Flight	4	3.87
Modulated Magnetic Signals	90	3.96
2.4GHz Phase Offset	24	4.04
WiFi+Sound Time-of-Flight	12	8.91
Steerable Antennas ToF	12	10.22
Bayesian Filter + WiFi Fingerprinting	96	1.56
WiFi+IMU Fingerprinting + Neural Network	36	1.96



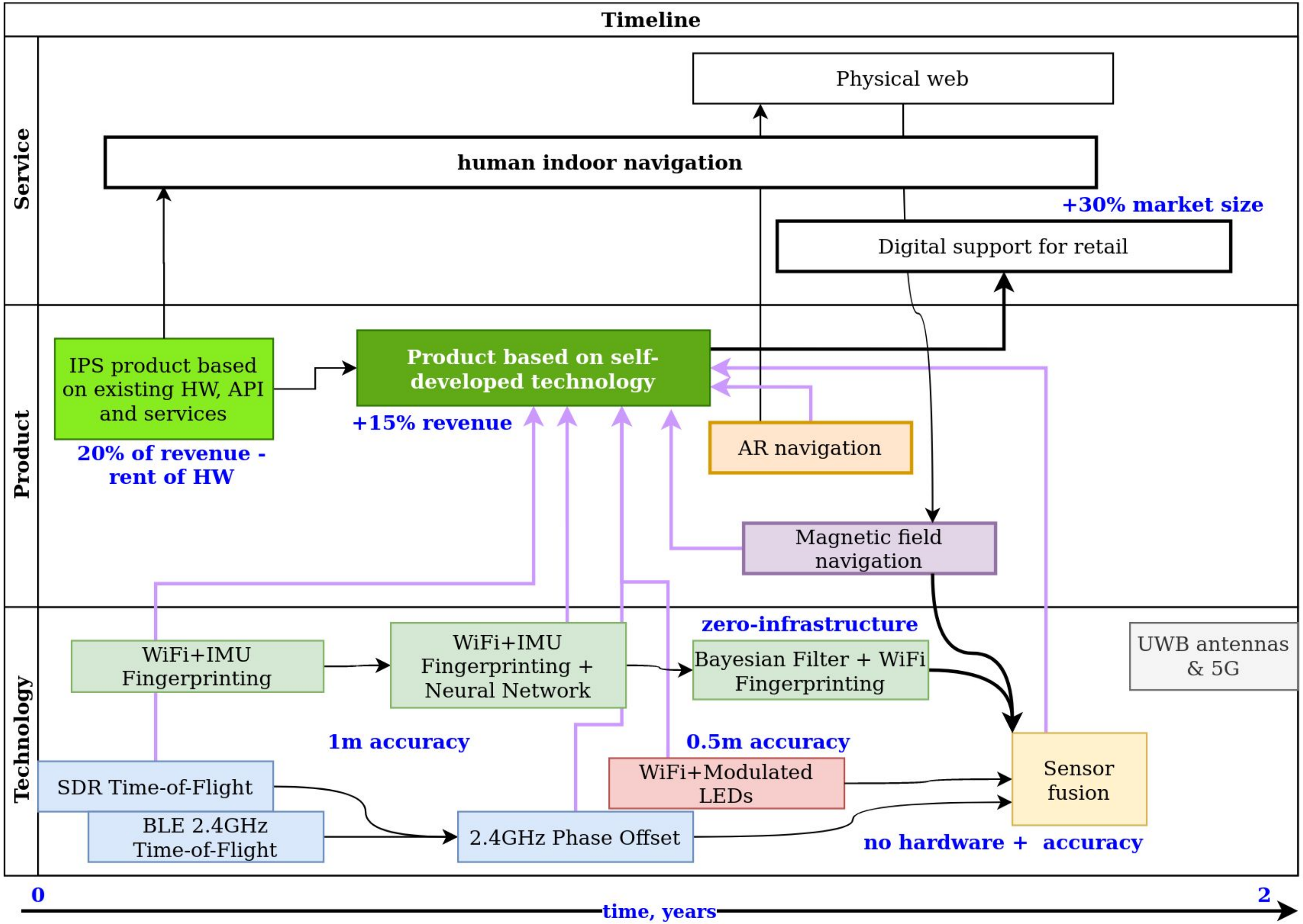
Lymberopoulos, Dimitrios & Liu et Al (2015). A Realistic Evaluation and Comparison of Indoor Location Technologies: Experiences and Lessons Learned. 10.1145/2737095.2737726.

Technology Strategy Vision

- Merge of indoor and outdoor positioning systems
- Privacy and security in IPS development
- Crowd-source mapping
- Zero-hardware systems
- "China Crisis Ebbs, But Tracking Apps Are Going Strong"- Chinese competitors
- Indoor Location of E911 Mobile Callers - USA market
- Physical web - IOT, connected devices, IPS using existing infrastructure

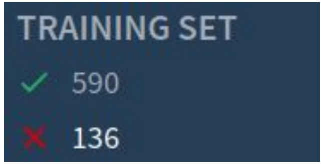
Deliver the product in least **development time**, reach average **accuracy.**

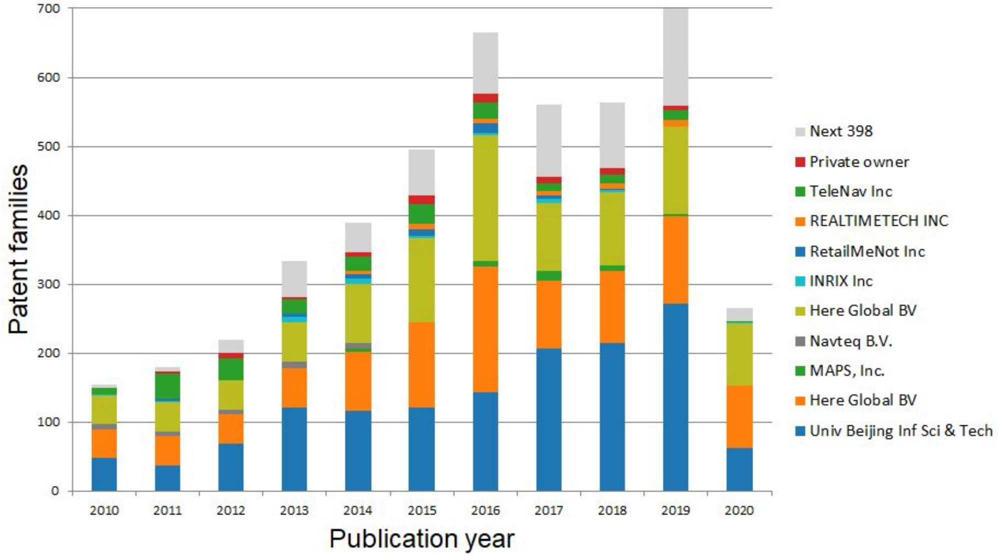
Timeline

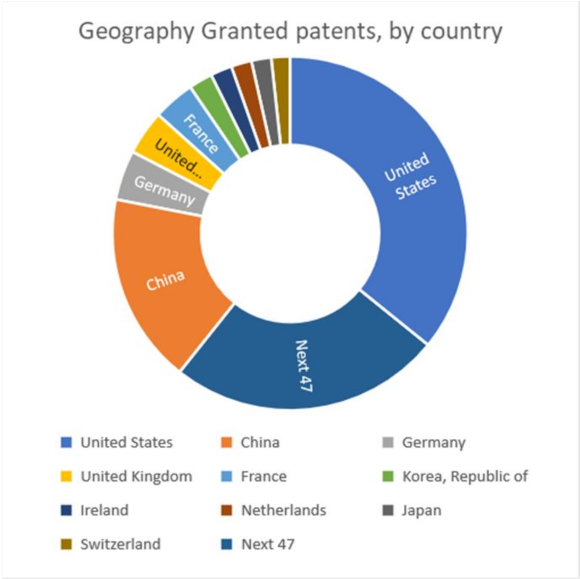


Timeline
Service
Product
Technology
Physical web
human indoor navigation
+30% market size
Digital support for retail
IPS product based on existing HW, API and services
20% of revenue - rent of HW
Product based on self-developed technology
+15% revenue
AR navigation
Magnetic field navigation
zero-infrastructure
WiFi+IMU Fingerprinting
WiFi+IMU Fingerprinting + Neural Network
Bayesian Filter + WiFi Fingerprinting
UWB antennas & 5G
1m accuracy
0.5m accuracy
SDR Time-of-Flight
BLE 2.4GHz Time-of-Flight
2.4GHz Phase Offset
WiFi+Modulated LEDs
Sensor fusion
no hardware + accuracy
0
2
time, years

Intellectual Property

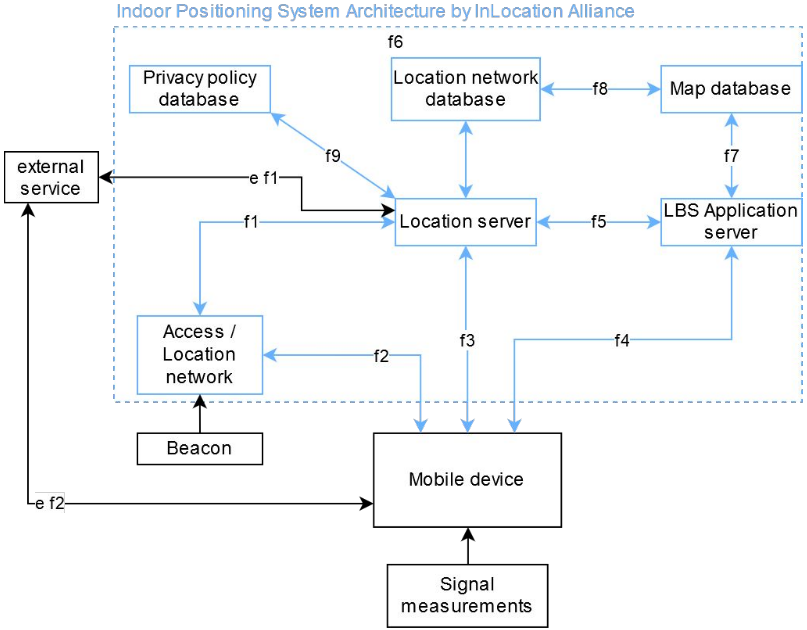


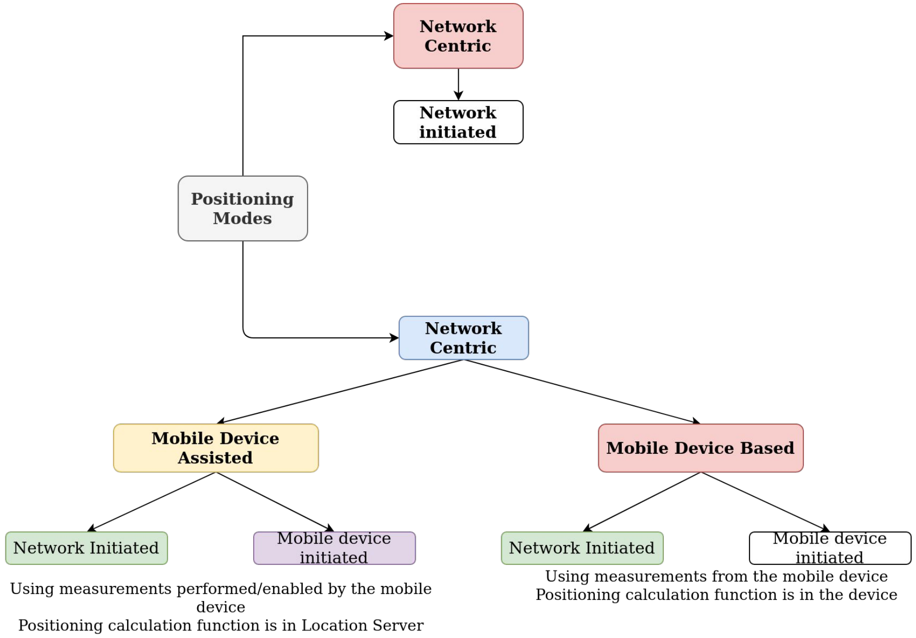




	Univ Beijing	Here Global	MAPS	Tile	Navteq	REALTIMETECH	TeleNav	Private owner	Next 398	TOTAL
indoor navigation	459	258	3	6	10	5	64	41	492	1597
Unrelated	568	778	32	27	27	31	124	0	42	2445
TOTAL	1027	1036	35	33	37	36	188	41	534	4042

System Architecture



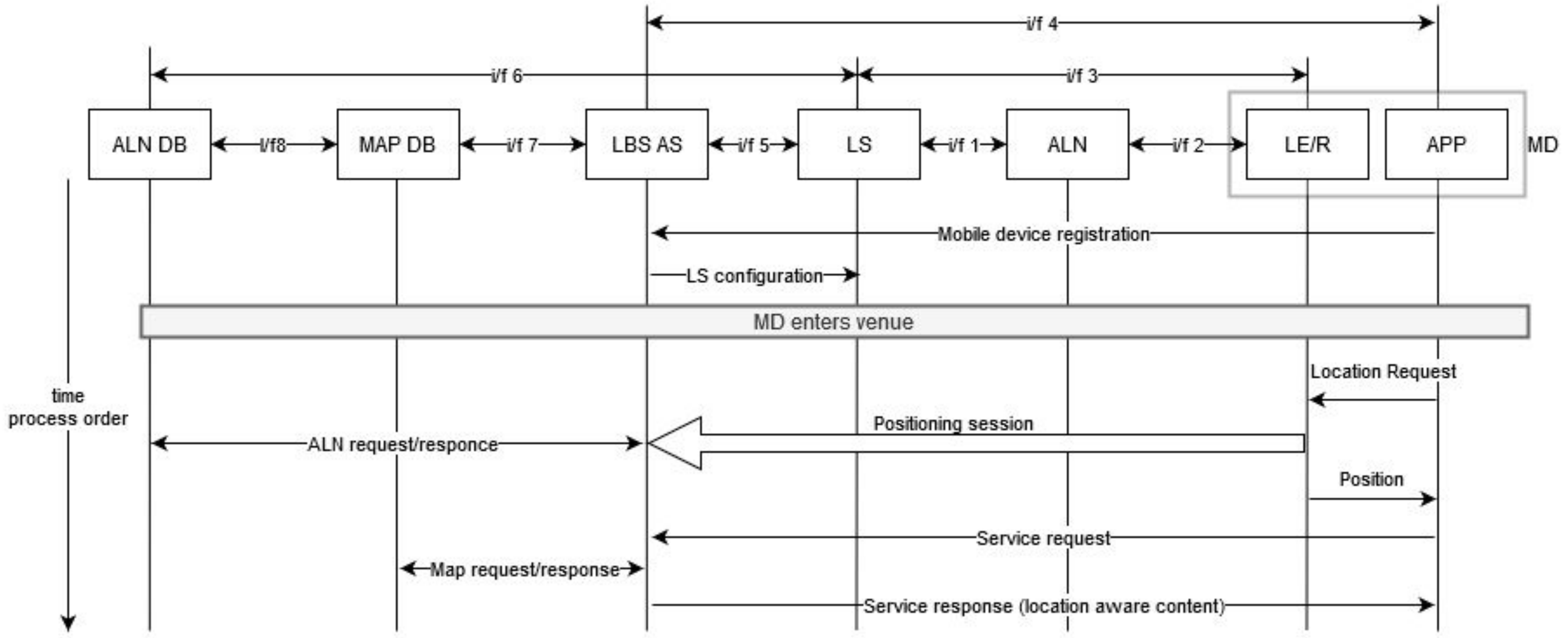


I. Alliance, “ILA system architecture release 1.0,”openmobilealliance.

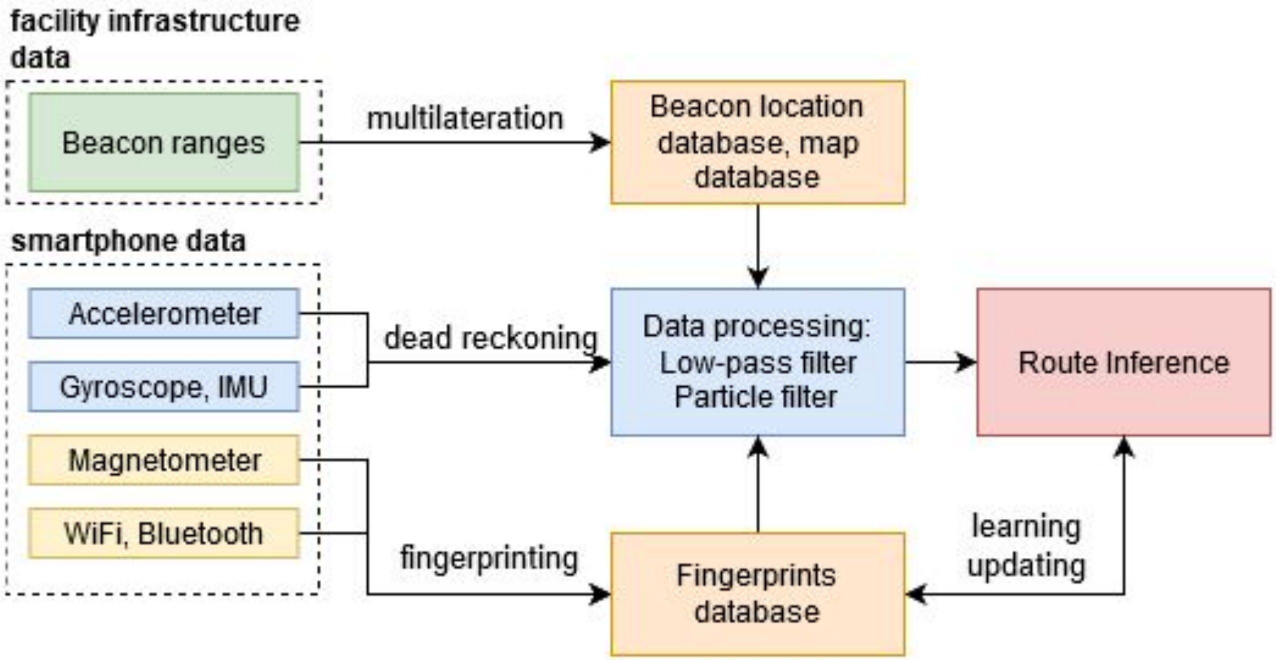
System Architecture

- Server based systems can be provided by an external vendor - buying a service
- Server based systems are enough cost effective to be used (development of server platforms in 2020 is enough to not care about signal processing on the local devices)
- Mobile device based are harder in development and support
- Mobile device based systems may not require external server and can be run locally - stable work with no internet connection
- Once operating, mobile device based are cheaper, because no server support and rent needed - costs are on user side. Important for scalability (if one million of users will use system, some additional traffic management will be required)
- Emergency help services shall not depend on internet connection - broadcast systems, mobile device used as transmitter - mobile device initiated systems
- In some cases network initiated positioning can be useful. For example, if ultrasound waves are used for positioning, sound transmission will happen over short periods of time defined by network, this will reduce level of noise.

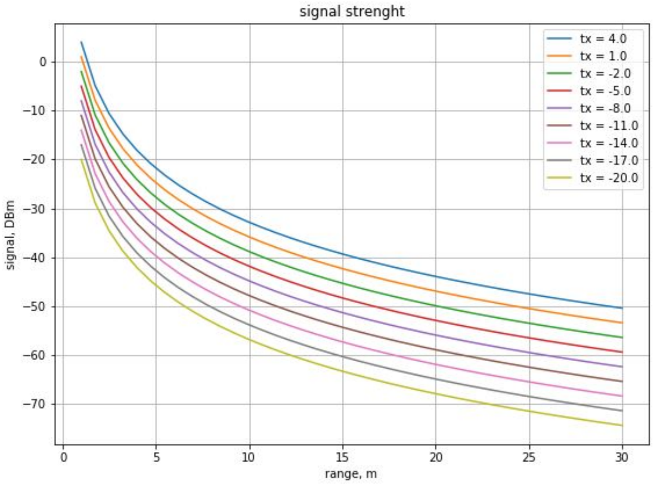
Location aware content example by ILA



System Architecture



Technical feasibility



Log-distance path loss model is formally expressed as:

$$PL = P_{Tx_{dBm}} - P_{Rx_{dBm}} = PL_0 + 10\gamma \log_{10}\frac{d}{d_0} + X_g,$$

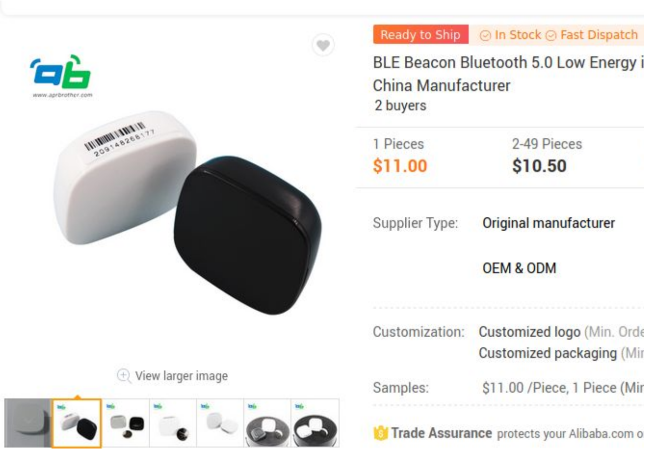
where

P L is the total path loss measured in Decibel (dB)

The free-space path loss (FSPL) formula:

$$\mathrm{FSPL(dB)} = 20\log_{10}(d) + 20\log_{10}(f) + 92.45$$

Bluetooth Specification	Bluetooth 4.0+
Frequency	2.402GHz - 2.480GHz
Transmit Power	4 to -20dBm With 9 Options
Receiver Sensitivity	-96dBm

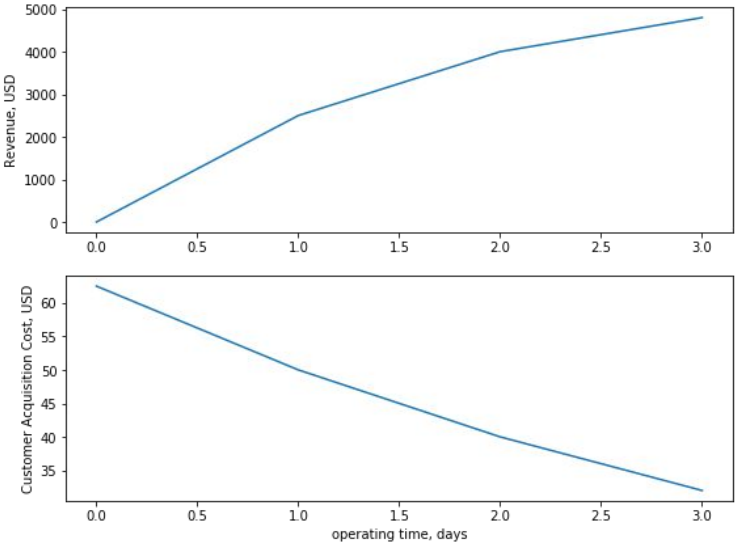


For BLE, we the normal conditions are as in figure above: with normal operating range of 30m, transmitter power in [4 DBm, -20 DBm] range, receiver sensitivity in range of -40 DBm, -60DBm.

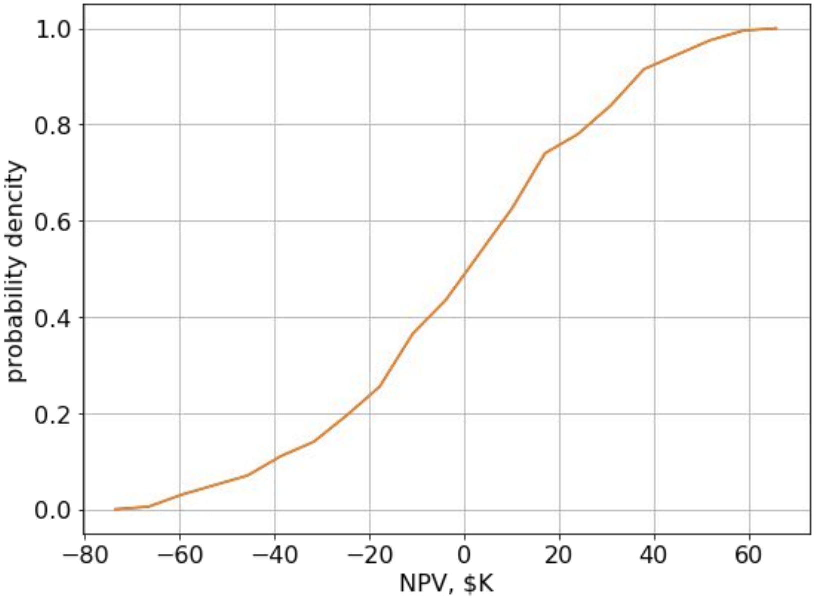
Financial valuation

	$K											
	Y1				Y2				Y3			
	q1	q2	q3	q4	q1	q2	q3	q4	q1	q2	q3	q4
MANAGEMENT												
wages	4	7	7	7	14	14	18	18	18	18	18	18
office			1	2	3	3	3	3	3	3	3	3
ENGINEERING												
system programming	0	1	2	3	3	3	3	3	3	5	5	5
web platform	0	3	6	6	8	8	8	8	8	5	5	5
hardware implementation	1	1	2	3	3	3	3	3	3	5	5	5
DRM	0	0	2	2	2	2	2	2	2	2	2	2
INTEGRATION AND SUPPORT												
fees							2	2	3	3	3	3
maintenance	0	0	4	4	4	4	6	6	6	6	6	6
modifications	0	0	0	0	2	2	4	4	4	4	4	4
MARKETING												
conferences	4	4	4	4	12	8	8	8	8	8	8	8
trials	0	5	5	6	8	10	15	22	31	44	63	90
web	1	1	3	3	3	3	5	5	7	7	7	7
COSTS	-10	-22	-36	-40	-62	-60	-77	-84	-96	-110	-129	-156
SALES		10	20	30	30	50	80	90	105	128	164	217
FREE CASH FLOW	-10	-12	-16	-10	-32	-10	103	6	9	18	35	61
cum fcf		-22	-38	-48	-80	-90	14	20	29	47	82	143
investment needed						100						

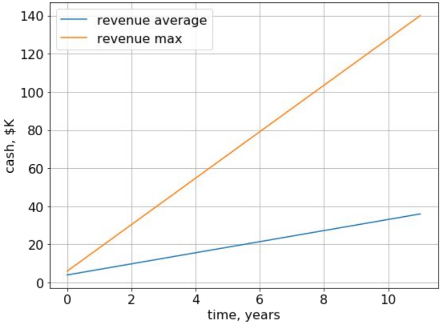
Financial valuation

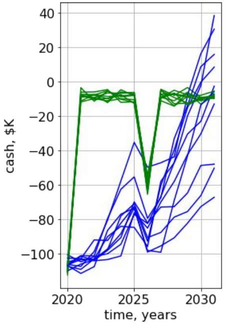


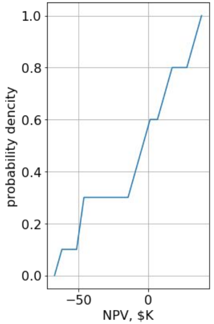
Customer acquisition cost diagram



Value at risk gain curve







Positioning

IndoorAtlas	Android or iOS SDK, MapCreator2 for Android mobile application	• Geomagnetic fingerprint maps • Pedestrian Dead Reckoning with gyroscope and accelerometer (IMU sensors) • Wi-Fi signals • Bluetooth beacons • Barometric height information
Navigine	Mobile app on iOS/Android.,web-interface/API	• BLE • Wi-Fi • UWB
Indoo.rs	SDK-free Indoor Positioning with the Location Based Engine- based on REST-API	• iBeacons • Sensor Fusion • SLAM Engine™ technology
WRLD	Android SDK and iOS SDK and API	• Bluetooth beacons • receiver antenna arrays • WiFi • short-range radio Ultra Wideband
INFSoft	The SDK is available for android and iOS as an HTML5 plugin. Also they use of frameworks such as PhoneGap or Xamarirn is possible.	• Wifi • BLE Beacons • UWB • RFID • camera systems

	Products
P1	Mapsted navigation deluxe
P2	HERE Indoor Positioning (SDK & radio mapper)
P3	IndoorAtlas
P4	VisioGlobe indoor navigation
P5	Google VPS (visual positioning system)

index	sensors
T1	GSM / 3G / 4G (LTE)
T2	compass, magnetic fields
T3	Wi-Fi
T4	Bluetooth
T5	accelerometer, gyroscope, pedometer
T6	UWB antennas
T7	Barometer
T8	Camera
T9	RFID, NFC, QR code

	Products				
	current				future
Markets	p1	p2	p3	p4	p5
positioning	x	x	x	x	x
marketing	x		x		x
analytics			x	x	x

Technologies

T1	T2	T3	T4	T5	T6	T7	T8	T9	**Processes**	p1	p2	p3	p4	p5
x	x	x					x	x	geofencing			x		x
		x	x		x			x	asset tracking			x	x	
x	x	x	x	x		x	x		human real-time positioning	x	x	x	x	x
	x	x	x						queue management			x	x	
		x		x	x	x		x	Sensor Fusion SLAM			x		
x	x	x	x	x	x	x	x		map creation	x	x	x	x	x

	T1	T2	T3	T4	T5	T6	T7	T8	T9
mature				x					
growth			x		x	x		x	
emerging		x							
declining	x						x		x

Product phase	p1	p2	p3	p4	p5
Research			x	x	x
Development	x	x	x	x	x
Delivery			x	x	
Support	x	x	x	x	

Validation

The tech background is validated by comparison of scientific publications and analysis of the existing solutions.
The business model was sequentially developed to satisfy four fits model.
Expert validation. (IndoorAtlas expert interview, customer interview)

1. W. Sakpere, M. A. Oshin, and N. Mlitwa, “A state-of-the-art survey of indoor positioning and navigation systems and technologies,”South African Computer Journal,vol. 29, pp. 145–197, 2017.
2. M. Kjærgaard, “Indoor positioning with radio location fingerprinting,” 04 2010.
3. R. F. Brena, J. P. Garc´ıa-V´azquez, C. E. Galv´an-Tejada,D. Mu˜noz-Rodriguez, C. Vargas-Rosales, and J. Fang-meyer, “Evolution of indoor positioning technologies: A survey,”Journal of Sensors, Mar 2017.
4. Infsoft, “Indoor positioning and services white paper,” 2019.
5. R. Bernard, “Indoor positioning systems,”Security Industry Association, 2017.
6. IndoorAtlas / Vanson Bourne, “A 2016 global research report on the indoor positioning market,” p. 6, 2016.
7. B. Li, T. Gallagher, C. Rizos, and A. Dempster, “Using geomagnetic field for indoor positioning,”Journal of Applied Geodesy, vol. 7, 11 2013.
8. I. Alliance, “ILA system architecture release 1.0,”openmobilealliance.
9. Indoor navigation market review by iBecom, June 4 2015
10. Geofencing market guide, Justin Croxton, Sept 26 2019
11. Thaljaoui, A., Val, T., Nasri, N., & Brulin, D. (2015). *BLE localization using RSSI measurements and iRingLA. 2015 IEEE International Conference on Industrial Technology (ICIT).* doi:10.1109/icit.2015.7125418

Conclusions & Lessons Learnt from TPR:F/TPR:A

The indoor navigation product strategy tool is in development now.

It was proven to be viable by customer discovery process and by revenue model & calculation.

However in order to succeed this idea requires:

- to be accurate - proved to be possible but requires lot of engineering
- to be convenient - depends on the way of realization and would require continuous improvements
- the acceptance of the market segment, which shall be accurately chosen
- complexity of either software or hardware

References

1. S. Walden, “The “indoor generation” and the health risks of spending more time inside,” 05 2018.
2. R. Mautz, “Indoor positioning technologies,” 2012.
3. W. Sakpere, M. A. Oshin, and N. Mlitwa, “A state-of-the-art survey of indoor positioning and navigation systems and technologies,”South African Computer Journal,vol. 29, pp. 145–197, 2017.
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5. R. F. Brena, J. P. Garc´ıa-V´azquez, C. E. Galv´an-Tejada,D. Mu˜noz-Rodriguez, C. Vargas-Rosales, and J. Fang-meyer, “Evolution of indoor positioning technologies: A survey,”Journal of Sensors, Mar 2017.
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9. B. Li, T. Gallagher, C. Rizos, and A. Dempster, “Using geomagnetic field for indoor positioning,”Journal of Applied Geodesy, vol. 7, 11 2013.
10. L. Hou, Y. Li, Y. Zhuang, B. Zhou, G. Tsai, Y. Luo, and N. El-Sheimy, “Orientation-aided stochastic magnetic matching for indoor localization,”IEEE Sensors Journal,vol. 20, no. 2, pp. 1003–1010, 2020.
11. I. Alliance, “ILA system architecture release 1.0,”openmobilealliance.
12. Indoor navigation market review by iBecom, June 4 2015
13. Geofencing market guide, Justin Croxton, Sept 26 2019
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15. Lymberopoulos, Dimitrios & Liu et Al (2015). A Realistic Evaluation and Comparison of Indoor Location Technologies: Experiences and Lessons Learned. 10.1145/2737095.2737726.

Thanks!

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