Bluetooth an Optimal Solution for Personal Asset Tracking: A Comparison of Bluetooth, RFID and Miscellaneous Anti-lost Traking Technologies

ARTICLE · MARCH 2015

DOI: 10.14257/ijunesst.2015.8.3.17

3 AUTHORS, INCLUDING:

Dr. Saleem Ahmad

University of Electronic Science and Techn…

8 PUBLICATIONS **3** CITATIONS

SEE PROFILE

Muhammad Ziaullah

University of Electronic Science and Techn…

17 PUBLICATIONS **5** CITATIONS

SEE PROFILE

International Journal of u- and e- Service, Science and Technology
Vol.8, No.3 (2015), pp.179-188
http://dx.doi.org/10.14257/ijunesst.2015.8.3.17

Bluetooth an Optimal Solution for Personal Asset Tracking: A Comparison of Bluetooth, RFID and Miscellaneous Anti-lost Traking Technologies

Saleem Ahmad, Ruoyu Lu and Muhammad Ziaullah

School of Management and Economics
University of Electronic Science and Technology of China
saleem.marral@yahoo.com

Abstract

This paper aims to present a comprehensive study for various Asset Tracking technologies. Our study scales down from introduction of chief underlying tracking and localization principles to technologies and systems at higher level. At lower tier, we introduce schemes like triangulation, Time difference of Arrival (TDOA or trilateration), multilateration, Angle of Arrival (AOA), Doppler, Signal Strength (RSSI), Beam forming etc. At surfacetier, our primary focus has been laid on RFID and Bluetooth based technologies while an overview of other technologies like satellites (GPS), cellular (GSM) or data connectivity (WIFI) etc. An insight to associated schemes like Active and Passive, Indoor and Outdoor, and Behavioral Sensing augment this. Each technology is further analyzed with benefits and drawbacks for a tracking solution. After technical insight, we will focus our study on Personal Asset tracking and highlight the pros and cons of previously mentioned tracking technologies in line with five aspects; Accuracy, Budget, Energy, Host and Platform-independence. Within these five regimes, we tabulate the requirements of an affordable, efficient and practicable scheme and illustrate with current examples. We keep our focus on a common user who has a cell phone in-hand and resolve an optimal tracking solution within the resources available to him. As a consequence, we conclude Bluetooth Low Energy based tracking schemes to be optimal candidate. We foresee our endeavor to serve as a compendium for the readers who wish to get an overview of such technologies without going into discrete technical details, and propose the Bluetooth based tacking scheme as a viable and affordable solution for a common user.

Keywords: *Bluetooth, RFID, nLocator, Radio signals, Anti-lost technology*

1. Introduction

In recent decades, the wireless communication is revolutionizing our everyday life. Today we have stepped into the era where machines are talking to machines facilitating humans nearly in all aspects of life. The most illustrative example is the cell phone connectivity which has emerged more than a mere communication device to interactive smartphones reshaping business, health, entertainment, utility payments and else. With smartphones becoming our resource managers and facilitators, we deem them appropriate as a viable candidate as a tracking platform.

The extent of misplaced and lost valuables is a common, but sometimes, unnoticeable and serious problem. A survey conducted in 2012 at UK reveals that the British adults lose about 200,000 items in their entire lifetime cited by [1]. It is further depicted that most of the daily life, valuables are the key lost items like cell phones, house and car keys, sunglasses, wallets, documents etc. In resolution, we observe that a lot of research has been carried out in this regard which propose various schemes for a range of valuables

ISSN: 2005-4246 IJUNESST

and conditions, like, tracking of parked vehicles, files and documents, wallets, keys and other items at workplaces and homes, as well as, tracking of the kids, patients, elderly and pets etc. In the market, we also observe a plethora of anti-lost solutions for aforesaid valuables. In both cases, we observe that such anti-lost and tracking solutions use diverse technologies, which depend upon their application, environment and usability, like Satellite (GPS), Data Connectivity (WIFI), and Cellular (GSM) *etc*. Our observation stems from the fact that having so adequate and diverse solutions, these technologies are still not widely practiced.

The reason is twofold: 1) Although the proposed tracking solutions and commercial anti-lost and tracking devices offer good tracking accuracy, but they heavily depend upon the additional infrastructure and host platforms, like WIFI access or other means of data connectivity, satellites, cellular towers, specialized and pre-installed beacons or crickets, war-sensing of data etc. Therefore, such solutions are area-specific, host and services limited and budget hungry solutions. Most importantly, these solutions are not within the grasp of a common user, *i.e.*, none of these solutions are fully standalone and the user is dependent on several things for their operations. In essence, the currently proposed and offered anti-lost and tracking solutions are budget-hungry, platform-dependent and energy-starved solutions as far as a common user is concerned; 2) We also observed a vast ignorance in common public about the availability of these tracking solutions. In 2014, the results of the survey illustrate that only 94% of smartphone users in China and UK don't know about the viability of tracking schemes in their smartphones. Even the 95% who know about such solutions, are reluctant to use them primarily because of their high budget and limitations [1].

In this paper, we underline the core reasons behind this gap – Why tracking and anti-lost technologies have failed to evolve in our daily life? What are the limitations of the chief anti-lost and tracking schemes? We consider it worthwhile to first present the minimal insight of these technologies to abreast our readers with their functionality. Later, we comment on the shortcomings of each solution and discuss it from application point of view.

As a contribution, we propose the Bluetooth based scheme to be an appealing choice for anti-lost and personal tracking. We target the requirements of a common user who only has a cell phone (we consider its present day smartphone) and wants to track his lost or misplaced things. We observe Bluetooth tracking scheme to be energy-efficient, budget-friendly, platform independent and technologically proven. In here, the user can tag his valuables with button sized Bluetooth tokens, which are tracked from a Bluetooth utility from the user's smartphone. It works both indoors and outdoors without requiring any data connection, does not require war-sensing or pre-mapped data about the environment. It does not depend upon the host support and solely relies at the connectivity between the smartphone and the tagged object. The stipulated scheme can offer a range of tens of meters to about one hundred meter. Will these benefits be the only?

In this paper, we consider a common user who only has a cell phone and wishes to locate his misplaced items. Through elaborated and comprehensive summary of various tracking solutions as presented in this paper, it would be clear enough to deduce that Bluetooth based location estimator proves to be an optimal candidate. However, we will foresee that the user has to make a trade-off between 'location accuracy' and 'energy, budget, host and platform-independence'. We will further illustrate our findings with practical examples of Bluetooth based tracking applications. The chief example of the third party software is nLocator by Navior Inc. offered by iPhone, which tracks the Bluetooth tagged items from iPhone and iPad products. To realize the practicability to awareness of the public about this tracking service by iPhone, we conduct a survey, which reveals that only 5% of the smartphone users actually know about the availability of any such tracking facility provided by the iPhone.

This paper is structured in four sections. Section 1.0 presents brief background knowledge of chief tracking and localization schemes used in tracking systems. This is followed by a comprehensive summary of various tracking technologies being researched and presented as solutions in Section 2.0. Thereafter, we list down the requirements of a viable tracking solution as demanded by a common smartphone user in Section 3.0. Later, in Section 4.0, we give an overview of Bluetooth based tracking solutions that exists in the market with an example of nLocator in iPhone. The paper concludes with Section 5.0 providing an account of antilost and tracking technologies.

2. Fundamental Tracking Principles

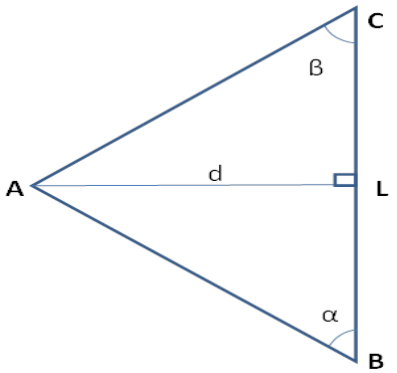
2.1. Triangulation, Trilateration, Multilateration

Global Positioning System (GPS) and the Local Positioning System (LPS) both apply the use of many transmitters to enhance a receiver to compute its environmental location. Many methods are possible, every with its virtues and restrictions. The vital factor in the techniques is the idea of direct path (LoS, or Line of Sight) [2-3]. In outcome, if the signal of the transmitter has not received the shortest path to the antennae, the length between them computed by the receiver could be inaccurate, because the receiver doesn't know the direction taken by the radio waves.

Consequently, three of the arithmetical methods are normally employed for computing the place of the receiver from signals accepted from various transmitters: triangulation, multilateration, and trilateration [2-3]. The final two are well known, though they should not be mistaken.

2.1.1. Triangulation

This is a very old mechanism, taken back from over 300 years ago, when the Greek philosophers applied it along with some astronomers to calculate their accuracy, the radius of the orbit of the Earth around the Sun [2-3].



$$d = \frac{\sin(\alpha)\sin\beta}{\sin(\alpha+\beta)}$$

Figure 1. Triangulation

Figure 1 Triangulation: Assume that you are at A, from where B and C are visible. If you are aware of their environmental location, then it's easier to navigate your individual locus with the compass help. This allows a person who observes to compute their place by measuring the two ways towards the two points of reference. Because the reference positions are clear, it is therefore easy to construct a three-sided polygon where one side and two angles of the triangle are known, with the bystander at the point three.

The details are enough to describe the triangle fully and thus deduce the observer's position. Triangulations that have transmitters need the angle of incidence (AoA, or angle of arrival) of the radio wave to be measured. It' accomplished by placing many aerials

sides by side: these measures an array of radio signals and to gauge the difference of the phase between the radio waves received by the aerials [4].

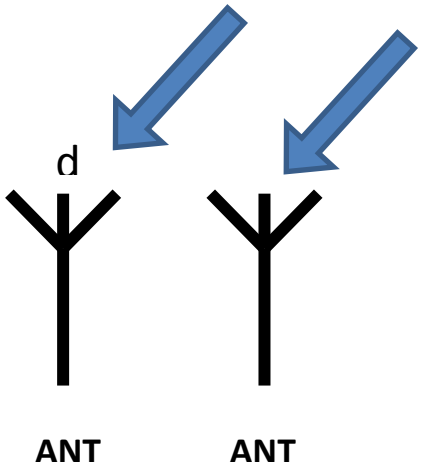


Figure 2. Array of Antenna that Makes it Possible for the Measuring of the Angle of Incidence of the Radio Waves, and therefore its Direction

Suppose the length between the aerials is small, then the occurrence front of the gesture might be taken straight, and the computation of the angle will be accurate. It's is as well conceivable to use a directional aerial to find the transmitter's position. The orientation of the antenna, which produce the strongest signal, shows the transmit direction. All that one has to do is measure from transmitters, which are known in order to apply triangulation [5].

2.1.2. Trilateration

This mechanism needs the length between the transmitter and the receiver to be calculated. This can be accomplished with the help Received Signal Strength Indicator, or else from the Arrival Time (AT) —or flight time (FT) in the Figure 3, given that the transmitter and the receiver are synchronized—for instance, by common time-base means, like in GPS [4, 6].

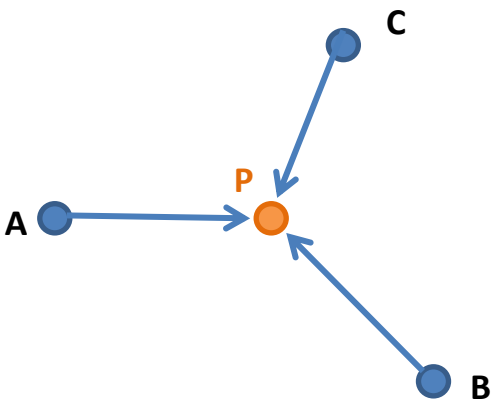


Figure 3. The Distance of the Arrows Relates to the Arrival Time at the Point P of the Transmission Signals by Three Masts A, B, and C

Consequently, Furey *et al.* (2012) argue that, when getting a signal from lone transmitter, one can position on a loop with the transmitter grounded. This argument is not very exact [6]. It is better with a pair of transmitters— presently there just two places possible: the two situations where the circles round the masts meet. Thus, enhancing the third transmitter allow us to reduce one of the two potentials.

2.1.3. Multilateration

By means of an only receiver responding to the signals from two coordinated transmitters, it is easy to calculate the dissimilarity between the times of arrival of the two waves at the receiver. Then the concept is the same to that of Trilateration, except that there is no circle or sphere, but it is a hyperbola (2D) or a hyperboloid—considered 3D. The pros of a multilateration are that the antenna does not require the transmitted instant signals—therefore no need to synchronize transmitter and the receiver. The signals can be kept simple and hence electronics [6].

2.2 Time of Flight Approach

A time-of-flight gadgets—also ToF Camera, is position imaging camera systems that determine distance using the known light speed, measuring the time of light of the signal between the camera and the object for every image point. The Time of Flight camera is a category of scanner-less LIDAR, where the whole scene taken with every laser or pulse of the light, as contrary to point by point by a laser girder for example when scanning LIDAR systems [7].

Time of Light products for civil uses started coming to practical around 2001, when the semiconductor processes turned to be fast enough for those machines. The arrangements wrap ranges of a few distances—say centimeters up to many kilometers. Time of Light gadget uses light pulses or a solo light pulse. The light illumination is switched on for a very brief period; the subsequent pulse of the light lights the scene and is then reflected by the subjects in the field of view. The camera lens collects the light and pictures it onto the radar or the array of the focal plane. Depending on the distance, then in a striking light encounters a lag argue by [6]. For instance light speed is approximated as c = 3.0 x 109 M/S, the delay is very concise, for example an object 2.5 m away will dawdle light by:

$$t_D = 2 \cdot \frac{D}{C} = 2 \cdot \frac{2.5\ m}{300\,000\,000\ \frac{m}{s}} = 0.000\,000\,016\,66\ s = 16.66\ ns$$

For the arrays, which are amplitude modulated, the illumination pulse width establishes the all-out range the camera can sobriquet. Say a pulse width of 50 NS, there is a limit of the range to:

$$D_{max} = \frac{1}{2} \cdot c \cdot t_0 = \frac{1}{2} \cdot 300\,000\,000\ \frac{m}{s} \cdot 0.000\,000\,05\ s = 7.5\ m$$

2.3. Angle of Arrival, Phase Measurement Approaches

The coordination of Spatial in wireless radar networks has much attention of late. In a distinctive solution, one or more nodes emit a signal and some property of that signal, for instance Angle of Arrival (AoA), is calculated and applied to come up with bearing or range. Lateration or angulation methods can therefore be used to guesstimate a node's plotting correspondingly [8].

Several mechanisms exist for establishing the position of the node grounding on bearing info (1), (2), (3), (4), (5)… there are scarce options for measuring AoA signal. The Cricket Compass is a gadget that applies ultra-sound with ability to establish orientation with regard to a several ceiling-mounted beacons. There are mounting two receivers in a short distance on a portable apparatus, and the phase diversity of the ultra-

sonic signal considered to verify hearing correspondingly [8]. Even though both CC and the approach measure signal phase variation to come up with AoA, the two schemes are dissimilar hardware, phase disambiguation methods, bearing derivation algorithms, and signal modalities.

2.4. Doppler Measurement

This is a form of satellite tracking technique for resolving the length between the receiver and the satellite during the closest approach in addition to the time itself. While the satellite approaches, the frequency seems to rise compared to the real transmission frequency. As it moves away, the rate of recurrence looks lowered. During the closest approach, the received and transmitted frequencies are often equal.

The calculation of frequency versus time results a Doppler curve. As the satellite occurs, the received frequency seems to fall but not constantly. The rate of variation begins of dense, is greatest in the period of closest approach and then tails off towards the end of the transit. This is since we are calculating the rate of variation in the component of the speed of the satellite along the line linking satellite with the receiver correspondingly [8]. The rate of variation is utmost at the spell of closest method and, if computed, can be employed in determining a passing distance.

2.5. Signal Strength (RSSI)

In Telecommunications, RSSI, which is referring to Receive Signal Strength Indicator, is determining the power that is within the receiver of radio signals. It's considered as a generic technology for the radio receiver metric. RSSI is often invisible to the user of the gadget that has the receiver, but unswervingly consumed by the operators' wireless networking—the IEEE 802.11 protocol specs correspondingly [8]. RSSI is frequently done in the IF (Intermediate Frequency) phase before the IF amp. Additionally, zero-IF structures, it is completed in the baseband signal chain, over the baseband amp. The output of RSSI is normally a DC level of analog. It can as well be sampled by internal ADC and the codes that results are available diametrically or through internal processor bus or any peripheral [9].

2.6. Beam Forming

Beam forming is a vital companion to 4 by 4 MIMO (Multiple Input Multiple Output) technology enhanced for the Wireless interconnection of elements. When it's incorporated, allows a dramatic upgrading of Wi-Fi 802.11ac/an implementation, range, reliability, and coverage. Beam forming a technique of signal processing employed to regulate the directionality of the emission and reception of the radio waves. The highly effective specie of beam forming is called a dynamic digital beam forming. The type is used advanced, Digital Signal Processing (DSP) on a clip algorithm to acquire full regulation over Wi-Fi signals. By forming many independent signal tracks to optimally emphasis radio exertion back and forth client gadgets embedded on per-packet basis, activity is enhanced dramatically. In the two-stream configuration case, it is easy to coxswain the power of the aerial arrangement in the autonomous spatial bearings linked with both data torrents, whilst concurrently avoids meddling.

3. RFID Technology and Schemes

RFID or Radio-frequency Identification is application of wireless system of non-contact that uses radio frequency of electromagnetic fields to transmit records from a tag affixed to an article, for the reason of automatic credentials and tracking. Some tags do not need power back up and instead energized by the fields of electromagnetic waves, used to read them.

The contemporary technology improvements, chipless RFID, devices have been created to suit the customer need, which will lead to high growth. The United States are the founders of the RFID business, and thus result in the top ranking market share of about 44%, and is predicted to develop at a CAGR of 24.2%, shadowed by Asia Pacific and Europe each by 29% [9]. They are forecasted to develop at a CAGR of 28.1% and 38.0% correspondingly. Chipless RFID applied in supply chain, retail, aviation, smart cards, public transit, healthcare etc.

Electronic Article Surveillance gadgets developed to assist venders increase their sales and secure their return by boosting open marketing opportunities while decreasing shoplifting and any internal stealing. EAS systems are devices, engineered and built for outstanding deactivation and detection performance, ease-of-use, aesthetics, and durability to match any décor. With innovative Ultra, Max acoustic-magnetic innovation behind several of our solutions, retailers experience virtually no false alarms [10].

RFID/ Radio Frequency Identification is the wireless appliance of electromagnetic fields for data transfer, for the function of detecting and tracking tags appended to the objects automatically. That tag has electronically kept details. Various tags—operated by induction of electromagnets from the fields created by magnets and produced close to the reader. RFID tags—applied in several industries. An RFID tag attached to an automobile throughout manufacture employed to track its advancement via the assembly line [10]. Because RFID tags are able to attach to cash, possessions, clothing, or even entrenched within people, the likelihood of reading directly linked details minus consent has alarmed serious privacy concerns. Imagine, the RFID globe market is approximated to surpass US$ 25 billion by 2014.

4. Bluetooth Technology and Schemes

Bluetooth technology is communications through wireless means envisioned to take the cable parts that are connecting fixed or portable electronic gadgets. The principal Bluetooth features are robustness, low cost, and low power [11]. Several Bluetooth Core Specification features are discretionary, conceding product discrepancy. The Bluetooth core devices comprise of an RF transceiver, protocol stacks, and baseband. The system gives facilities that allow the linking of gadgets and then exchange many categories of data between them. Many specifications of the core are not obligatory allowing the differentiation of the products [12].

Bluetooth profiles are descriptions of conceivable functions and indicate general performances that devices, which are Bluetooth enabled, employ for communication with other gadgets. Today's wireless technology implies that data transmitted from the device to the other invisibly, person to person [13]. This record, in the arrangement of electronic mails, contacts, photos, addresses and many more require a well-secured protocol. Bluetooth technology, from its beginning, has put a stress on the safekeeping while creating networks among the gadgets.

The nLocator technology allows one to take or leave their iPhones everywhere/ anywhere respectively. This can be an office, under the pillow, or at the conference, they won't lose forever. You will find them with ease. One is able to find their lost iPhones under the lost mode features [9]. If the phone gets lost, nLocator has a feature to lock the screen. It then sends a text with a number—anyone who will come across the phone can read the text, and then call you from the locked screen minus retrieving the rest of the data in the device. Consequently, if the device gets lost, simply put it in the lock mode. The nLocator will allow you to put a four-digit pin that would block anyone from retrieving individual data from iOS when they are on and connected onto the Wi-Fi [13].

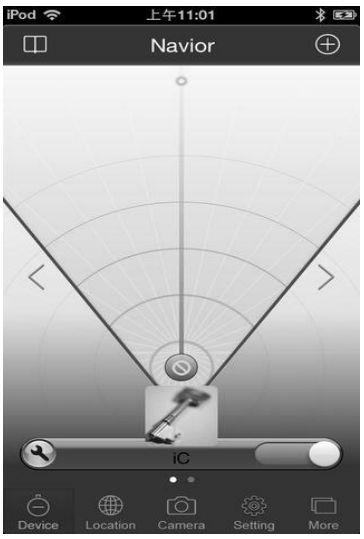


Figure-4(a): Snapshot of nLocator

Figure-4(b): nLocator assisted by GPS

Figure-4 : Snapshots of nLocator by iPad. In Figure-4(a), the Misplaced Valuable is Highlighted with Green dot and Person can Navigate in the Direction of Key. In Figure-4(b), a Person Can Also Switch to GPS and Find the Exact Place his Misplaced Valuables with the Help of GPS

iPhone is not only who offers the Bluetooth based tracking facility, some other Bluetooth tracking systems also have been proposed and prototyped in academic [14-15], and some of the authors proposed an indoor accuracy of 1.5m [16]. There is also a Bluetooth navigation technique incorporates the Bluetooth-WiFi conjunction used in Vicinity Marketing or Location Based Mobile Marketing [17], where consumers can pop up to get the information related to the shopping mall and about the products. The Nokia Research is aiming to integrate indoor localization via Bluetooth technology [18] with the aimed accuracy of 0.3m [19]. Moreover, the big giants of the industry are collaborating for a standardized protocol of WiFi-Bluetooth scheme for indoor navigation [20]. As mention before, all these solutions required pre-installed hardware and/or wireless fingerprinting of the area.

5. Miscellaneous Anti-lost/Tracking Technologies

Outdoor tracking technologies are used to track, especially small kids while they are away from their parents. This device makes it look as parents are just together with their kids all time. Outdoor Techniques: outdoor portable locator tracking gadget, anti-lost alarm, watches a child, child GPS tracker, and bracelets presented by [13]. PG88 major practical 11 purposes, including Global Positioning Systems, SOS emergency, platform, location, SMS positioning, electronic fence, track playback, alarm clock, remote listening, MP3/MP4 players, and digital photo frames.

An anti-theft device is any machine or technique utilized to avert or deter the unlawful misuse of items deliberated valuable. Stealing is one of the greatest customary and firstborn criminal behaviors [5]. From the discovery of the first-lock and solution to the presentation of RF tags and biometric recognition, anti-robbery systems have changed to balance the launch of innovations to people and the subsequent theft of them by other people.

Anti- burglary techniques are fabricated to raise the complexity of stealing smartphones to a deadly level. The type of system applied frequently dangles on the suitable level of theft. Let's say, saving money in an inner shirt pocket increases the complication of holdup above that essentially if a pocket remained on a rucksack, since

unlawful retrieve is made suitably harder. Approaches of robbery develop to diminish the trouble of larceny, augmented by fresher anti-theft logics. Since there is fruition on both edges and the communal viewpoint of theft, the maximum for embezzlement is very lively and severely relying on the atmosphere [12]. Gates in quiet residential areas has habitually leaves wide open, as the apparent thresholds for stealing are very great.

6. Conclusions

In conclusion, the three of the arithmetical methods are normally employed for computing the place of the receiver from signals accepted from various transmitters to enhance "Fundamental Tracking Principles." These incorporate techniques like triangulation, multilateration, and trilateration. RFID or Radio-frequency Identification is a vital application of wireless system of non-contact that uses radio frequency of electromagnetic fields to transmit records from a tag affixed to an article, for the reason of automatic credentials and tracking. RFID tags are applied in several industries. An RFID tag attachment to an automobile throughout manufacture can be employed to track its advancement via the assembly line. Because RFID tags are able to attach to cash, possessions, clothing, or even entrenched within people, the likelihood of reading directly linked details minus consent has alarmed serious privacy concerns.

Bluetooth technology is communications through wireless means envisioned to take the cable parts, which are connecting fixed or portable electronic gadgets. The principal Bluetooth features are robustness, low cost, and low power. Within the indoor tracking techniques, anti- burglary techniques are fabricated to raise the complexity of stealing to a deadly level. The type of system applied frequently dangles on the suitable level of theft. Let's say, saving money in an inner shirt pocket increases the complication of holdup above that essentially if a pocket remained on a rucksack, since unlawful retrieve is made suitably harder.

References

[1] S. Ahmad, R. Lu, and M. J. Hussain, "Never Lose! Smart Phone based Personal Tracking via Bluetooth." International Journal of Academic Research in Business and Social Sciences, vol. 4, no. 3, **(2014)**.
[2] J. Ash, S. Kyperountas, O. A. Hero, R. L. Moses, and N. S. Correal, "Locating the nodes: cooperative localization in wireless sensor networks." Signal Processing Magazine, IEEE vol. 22, no. 4, **(2009)**.
[3] R. L. Moses, D. Krishnamurthy, and R. Patterson, "An auto-calibration method for unattended ground sensors" IEEE International Conference on Acoustics, Speech, and Signal Processing **(2002)**; Orlando, USA.
[4] G. Sun, J. Chen, W. Guo and K. Liu, "Signal Processing Techniques in Network-Aided Positioning" IEEE Signal Processing Magazine, vol. 22, no. 4, **(2013)**.
[5] H. Aghasi, M. Hashemi, and B. H. Khalaj, "A Source Localization Based on Signal Attenuation and Time Delay Estimation in Sensor Networks", International Journal of Computer and Electrical Engineering, vol. 4, no. 3, **(2012)**.
[6] E. Furey, C. Kevin and K. Paul, "HABITS: A Bayesian Filter Approach to Indoor Tracking and Location." International Journal of Bio-Inspired Computation vol. 4, no. 2, **(2012)**.
[7] N. Chang, R. Rashidzadeh and M. Ahmadi, "Robust indoor positioning using differential Wi-Fi access points" IEEE Transactions on Consumer Electronics, vol. 56, no. 3, **(2010)**.
[8] Y. Zhou, C. L. Law, Y. L. Guan and F. Chin, "Indoor elliptical localization based on asynchronous UWB range measurement", IEEE Transactions on Instrumentation and Measurement, vol. 60, no. 1, **(2011)**.
[9] J. Sallai, V. Péter, and L. Á kos, "Radio Interferometric Quasi Doppler Bearing Estimation" Vanderbilt University Press, **(2009)**.
[10] Z. Zhen, "The Mathematical Connotation of Hetu and Luoshu" China City Press, **(2012)**.
[11] J. Chen, "Multimodal Wireless Networks: Communication and Surveillance on the Same Infrastructure" A Thesis presented to the IT University of Copenhagen, Copenhagen, **(2007)**.
[12] J. Ash and P. Lee, "Robust System Multiangulation Using Subspace Methods" Ohio State University Press, **(2008)**.

[13] M. Iskander, Z. Yun, and Z. Zhang, "Outdoor/Indoor Propagation Modeling for Wireless Communications Systems" IEEE Antennas and Propagation Society, AP-S International Symposium 2 **(2001)**; Boston, USA.
[14] K. C. Cheung, S. S. Intille and K. Larson, "An inexpensive bluetooth-based indoor positioning hack" 8th International Conference of Ubiquitous Computing Ex-tended Abstracts, UbiComp **(2006)**; California, USA.
[15] T. Fernandes, "Indoor Localization Using Bluetooth" University of Porto, **(2013).**
[16] A. Bekkelien, "Bluetooth indoor positioning" A Thesis presented to the University of Geneva, Switzerland, **(2012)**.
[17] Ace Marketing & Promotions, Inc., "Mobiquity Networks" New York, USA **(2013)** [18] Z. Deng, T. Xue and H. Cao, "Realization of A Bluetooth Network-Based Multi-Module System" 12th World Multi-Conference on Systemics, Cybernetics and Informatics, **(2008)** June 29 - 2 July; Florida, USA.
[19] F. Belloni, "Bringing Navigation Indoors" Nokia Research Center Radio Systems Laboratory, Finland **(2010)**
[20] T. Perry, "The Indoor Navigation Battle Heats Up", Available at: http://spectrum.ieee. org/tech-talk/consumer-electronics/portable-devices/the-indoor-navigation-battle-heats-up, **(2012)**.

