IoT: Architecture, Technology, Applications, and Quality of Services

Vidhyotma and Jaiteg Singh

Abstract A decade back "Internet of Things" (IoT) has transmogrified the automation technologies which comprises the physical entity, sensors, actuators, and controllers with Internet connectivity. However, several technological applied issues and challenges are pertaining to the interoperability of humans, things, and machines. Ultimately diversified application areas of IoT such as health care, transport management, smart home, and smart cities have increased the scope of this technology in future. The paper highlights the layered architecture of IoT, communication protocols used by each layer as well as applications and its technologies.

Keywords IoT · RFID · Smart objects · Wireless sensors · WPAN · WSN

1 Introduction

The term Internet of Things (IoT) was coined by "Kevin Ashton" in 1999 at "Procter and Gamble" (P&G) while connecting the latest scheme of RFID in the supply chain of that company [1, 2]. A decade later, the IoT was launched as new technology [3]. Road map of IoT as per "SRI consulting business intelligence" is given in Fig. 1. It shows when the number of objects linked with the Internet would be exceeded the number of persons in the universe [4]. The road map also shows the increase in application areas of IoT with the duration of time. IoT had started from the retail supply chain and later on benefitted medical and health, transport, manufacturing, pharmaceuticals and safety and security application areas.

The IoT has made possible to interact between Things to Human (T2H), Things to Things (T2T), Human to Human (H2H), Human to Things (H2T), at a virtual level

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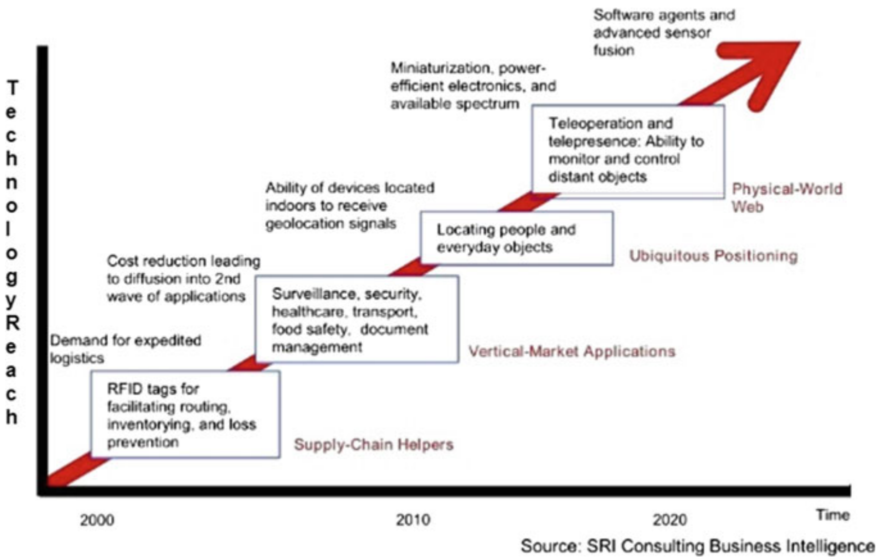

Fig. 1 Road map of the Internet of Things [35]

in daily routine life [5]. The IoT has added the latest dimension to this procedure by allowing interactions within smart objects. The omnipresence of communication network connects the objects "anytime, anyplace, any medium (wired or wireless) and anything or human" [6]. Figure 2 represents the diversified connectivity of IoT.

The IoT is a novel archetype which is hastily achieving height due to the recent advancement in wireless communications. The simple idea behind IoT is the prevalent existence of various objects or things with tags of Radio-Frequency Identification (RFID), different kinds of sensors, mobile phones, actuators, and so on as given in Fig. 3 [7].

It is implemented by assigning the address to the objects or human using any addressing scheme [5]. Different available technologies can be used to implement IoT. The basic structure of the IoT is based on smart devices, i.e., objects built with communication capabilities of Machine-to-Machine (M2M) [8]. The object can be of any type. It is necessary to assign an IP address to every device/object to provide the ability to transfer or receive data over the network [9]. Huge availability of IPV6s addresses is the major factor in the development of IoT technology. These smart things are able to make communication among them as well as to interact with the surrounding environment by interchanging, information, and data sensed about the environment [10]. During responding independently to the events of the real world and affecting them by the running processes which excite operation and allocate services along with or without the straight human intervention [11]. Actually, the IoT is a network of uniquely addressable interlinked objects, which is worldwide established on the low-power communication protocols [12]. IoT paradigm is represented in Fig. 4. The process consists of a large number of heterogeneous objects

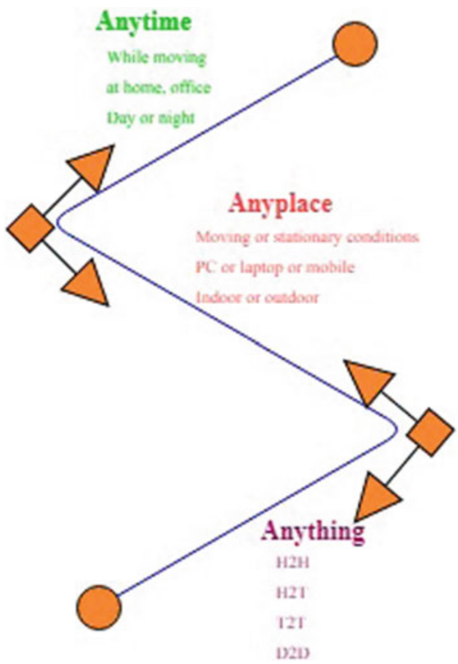

Fig. 2 Connectivity of IoT [36]

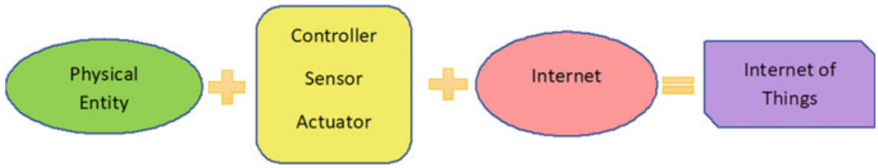

Fig. 3 Internet of Things

[13]. Any wireless communication technology can be used to communicate within objects but it is very costly to provide each object with its personal id on the web [3]. The general IoT deployment architecture consists of four layers, but the underneath and intermediate technologies of each layer vary according to the application. IoT can be implemented with different technologies like Wireless Private Area Network (WPAN), RFID, IPV6, etc. and has diversified application areas.

This paper is divided into seven sections. The introduction of IoT was given in Sect. 1. Section 2 describes the architecture of IoT and Sect. 3 explores the technologies used in IoT. Sections 4 and 5 discuss the applications of IoT and quality of services, respectively. Section 6 concludes the paper and Sect. 7 leads to the future scope in the field of IoT.

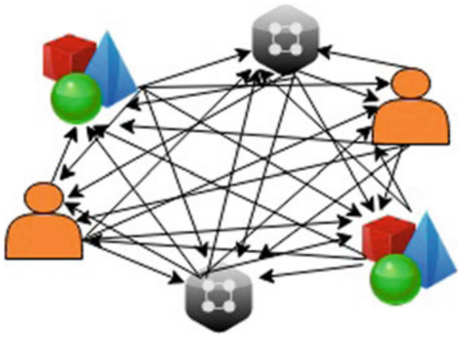

Fig. 4 Internet of Things paradigm [18]

2 Architecture of IoT

IoT works in the bottom to top approach. Sensors gather data using the smart devices, process this data using controllers to take decisions, and then communicate to the devices or persons for implementation [14]. User or applications are in the topmost layer and the technology, assigning addresses to smart objects, and communication media used are in the bottom layer. Smart objects, sensors, and software like micro-controllers used to process data are in the middle layer. The architecture of IoT consists of four layers as shown in Fig. 5. The functionalities of each layer have been briefly discussed below.

2.1 Application Layer

It is the user interface in the top of the architecture which is responsible for delivering several applications to the different users or industries in IoT [5]. Increasing usage of RFID technology in numerous applications increases the scope of IoT [7]. This application can belong to different industry verticals such as logistics, manufacturing, public safety, environment, food and drug, health care, retail marketing chain, and so on [5]. Session generation for every user and designing of the user interface for each application is also the part of this layer.

2.2 Edge/Transport Layer

The edge/transport layer utilizes the interface between bottom hardware surface and top application surface [12]. It is responsible for critical function that is device management as well as information management. It has responsibilities of all the issues like filtering and preprocessing of data, access control, analyzing of semantic, discovery of information, i.e., Electronic Product Code (EPC), information facility data analytics, and Object Naming Service (ONS). Middleware surface works in bidirectional mode [15].

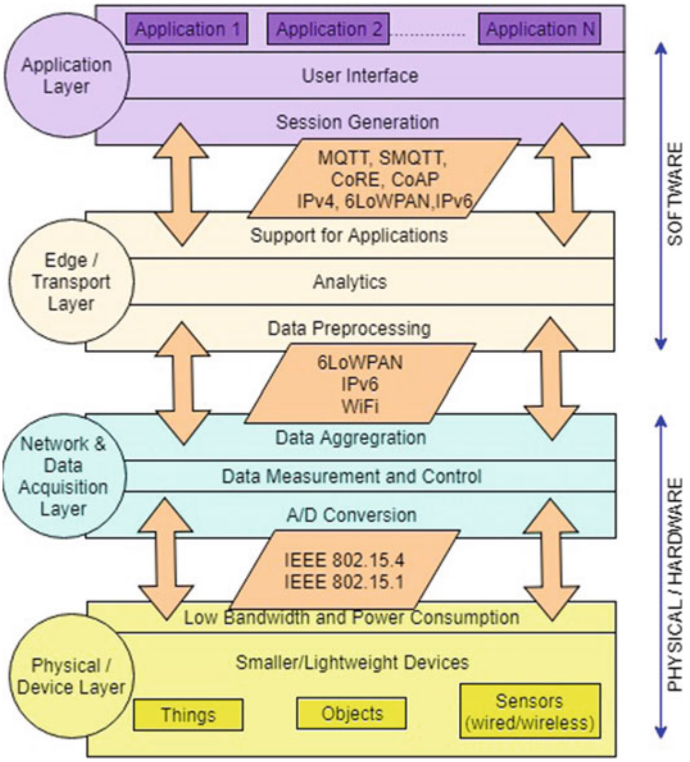

Fig. 5 Layered architecture of IoT

2.3 *Network and Data Acquisition Layer*

This layer is responsible for publishing, message routing, and subscribing, and based on the requirement it can perform the cross-platform communication. Data handling and conversion happen in the first stage of this layer [12]. Data measurement, aggregation, and control are the major functions of this layer.

2.4 *Physical/Device Layer*

Physical layer consists of sensors/constrained devices (sensors/actuators). According to Internet Engineering Task Force (IETF) publication RFC7228 constrained devices can be classified into three classes and are shown in Table 1 [16].

Sensors can be wearable or implantable and can record continuous or discrete signals. Figure 6 shows the categorization of different types of physiological sensors. RFID tags and readers, sensor networks, embedded systems, or other sensors form device layer [10]. The layer is responsible for primary data generated by these

Table 1 Constrained devices according to IETF (RFC7228)

	Class 0	Class 1	Class 2
RAM (KB)	10 (less than)	~10	~50
Flash (KB)	100	~100	~240
Protocols	MQTT, CoAP, EXI	UDP, CoAP, TLS, DTLS, HTTP	All protocol stacks
Cost	Low	Low	High

sensors, things, or objects. RFID tags and sensor networks provide identification. Embedded systems are used to collect the information, to store information, processing of information, actuation, control, and communication [17].

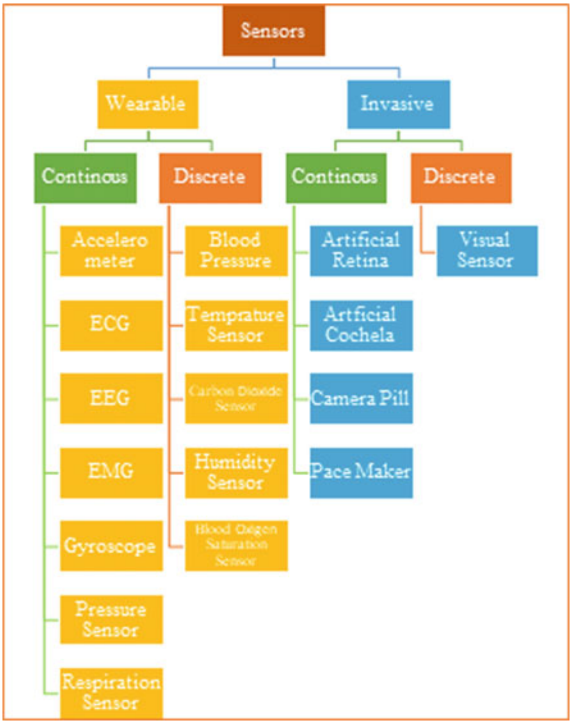

Fig. 6 Classification of sensors

3 Technologies Used in IoT

IoT can be implemented with the integration of several technologies. As the name reflects, IoT is the technology to make information or data available on the Internet to remotely control the real-time application [18]. The IoT syntactically consists of two terms; the first one depicts the vision of IoT, i.e., "network-oriented," and the other focuses on the common "objects" to be merged into a regular structure [3]. The actual definition of IoT is obtained from a "Objects oriented" [8]. The underneath technologies used in IoT are given below.

3.1 Wireless Private Area Network (WPAN)

The WSN can be used to create wireless private area network. These can be RF modules, Zigbee modules [9]. WPAN follows the IEEE 802.15.4 standards. It works in three frequency bands 868, 915, and 2.4 GHz. The parameter details of these frequency bands are given in Table 2 [19, 20]. In WPAN, devices are denoted as nodes. It can sense surroundings and communicate data using wireless connections to and from the monitored field [21]. The WPAN can control the environment and makes it able to interact with computers or human beings/different nodes and the surrounding environment [22]. Possibly, multiple hops forward data to the controller functioning as a sink node which can use the data locally or it can be linked to the other networks [22]. The nodes might be mobile or immobile and can be heterogeneous or homogeneous [23].

Table 2 WPAN frequency bands

Bands	Parameter							
	No. of channels	Frequency spectrum	Modulation scheme	Symbol rate/s	Symbol type	Chips/s	Unlicensed	FCC band
868 MHz	1	868 MHz	BPSK	20	Binary	0.3 Kb	Europe	–
915 MHz	10	902–928 MHz	BPSK	40	Binary	0.6 Kb	US	Industrial
2.4 GHz	16	2.40–2.48 GHz	O-QPSK	250	16-bit array	2 Kb	Worldwide	Scientific

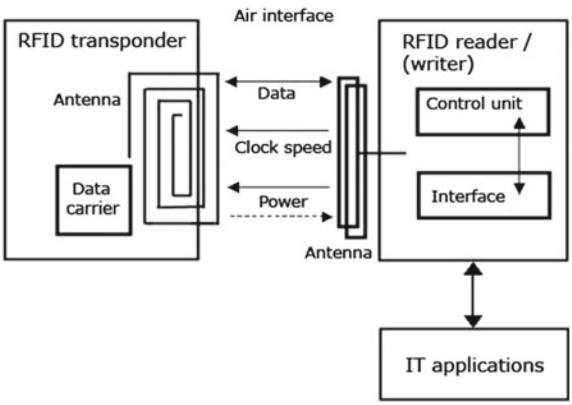

Fig. 7 Working within "RFID" technology

3.2 Radio-Frequency Identification (RFID)

RFID is a wireless mechanics that use identification code to scan or recognize any person, animal, substance, product, car, or any other object that contains a tag [24]. This technology is the combination of three articulates: tag, reader, and antenna. A tag is known as a transponder, which has a printed circuit board and/or semiconductor. A reader is further known as a transceiver, which decodes existing information by the transponder or tag. Usually, an antenna is established on the tag, which receives or transmits the power in the form of the radio frequency. The data is transmitted through antenna and reader receives the data [6]. RFIDs are available in different frequency ranges and are chosen according to the applications as shown in Fig. 7 [7, 22].

- Low-density up to 30 MHz → up to 0.01 m for Close-joint

Remote Joint:
- Lower than 135 KHz → up to 1 m 500 cm
- 13.56 MHz(closeness) → 0.1 m
- 13.56 MHz(environs) → 0.5–3 m

Long Range:
- 433, 868 or 915 MHz → 0.5–50 m
- 2.45 GHz → 10–100 m
- 5.8 GHz → 10–1000 m (Under expansion)

3.3 Internet Protocol Version 6 (IPv6)

IPv6s huge increase in address space played a major role in the development and growth of IoT. According to the research community, the address space expansion means that every atom in the universe can be assigned an IPV6 address and still

100+ piles of earth addresses are left to assign [25]. Samsung Electronics, Silicon Labs, Nest Labs, Yale Security, Free scale Semiconductor Big Ass Fans, and ARM have joined hands together to form the "Thread Group" to enhance the application capabilities of "Internet of Things" connectivity [26]. The thread will avail the maximum outcome of the number of existing standards including 6LoWPAN (Little-capability wireless personal area networks), IETF IPv6, and IEEE 802.15.4 [26]. It is already used inside the nest-based devices, i.e., Wi-Fi makeable smoke detectors and thermostats made by Google [24, 27]. US National Power NIC predicts "by 2025; Internet nodes may reside in everything in daily life like vehicles, paper documents, furniture, food packages, medicines, and more" [2].

4 Applications of IoT

Potentiality of applying the IoT in different domains like industry, domestic, retailing, defense, health, education, and other various fields is very high; rather in some domains it is already in use and research is going on. Few industrial and domestic applications that come under the umbrella of IoT are given below.

4.1 Retail Supply Chain

The retail supply chain is managed well with the help of RFID identification of goods and the smart-shelf concept is very useful in placing and picking up the things in retail stores [3]. The owner is always aware of stock status and sales and can easily maintain the purchase orders for goods.

4.2 Medical and Health

Wearable sensors can be used to locate, in the hospital, both doctors and nurses along with the patients at any point in time [26]. Some vital functions of the human body, i.e., cholesterol levels, sugar level, blood pressure, temperature, and the heartbeat rate can be monitored through the IoT system. In case of a heart attack, stimulate the heart muscle through the combination of the sensors implantation. Data can be recorded wirelessly using IoT technology [28].

4.3 Aid for Aged and Physically Disabled Persons

IoT is very beneficial for an aged and physically disabled person using wearable smart identity sensors. These wireless sensors transmit the health status of a person and can also alarm for help in case of an emergency condition [29].

4.4 Transport

RFID technology is already in use in vehicles production units and traffic control systems. Luxury vehicle, i.e., buses, cars, trains, and airplanes are equipped with actuators with increased processing powers and advanced sensors which help in reporting pressure in tires, the location of a vehicle. Deployment of IoT increases quality control, improves logistics, and improves customer services [15].

4.5 Manufacturing

In manufacturing units, IoT is used to remotely optimize production processes and keep the record of manufactured items on the daily, monthly, or yearly basis to calculate the turnover of a company using unique identity for each product. Ingredient ratio in a product can also be tracked through sensors [3].

4.6 Safety, Security

The home safety and security are must in today’s life. There are lots of wirelesses sensors which are integrated with the IoT to provide safety by providing information on the Internet through a mesh network. One can remotely control the power system, locking system, and can also be aware of the water status of own home [30].

4.7 Automation

Internet of Things is playing a major role in the embedded industry. Smart homes, smart cities, and industry 4.0 are the main application areas of automation [17]. Low-power and cost-effective embedded devices are developed with the help of smart sensors which create the mesh network and transmit data on the Internet [31].

4.8 Pharmaceutical

In pharmaceutical companies, it is the time of demand to make customer's life risk free. It can be possible by IoT smart labeling technique. By providing smart labels to drugs it will be helpful to keep track of its quality, quantity, and also aware the patient about its storage and dosages details [32].

Few IoT applications along with their IoT properties are given in Table 3.

5 Quality of Services (QoS)

The IoT has an excess of applications, resources, and the network of components which inherently consist of a complex and shared system. Lots of devices in it are dynamic and heterogeneous in terms of energy, communication, and computation. Due to this, many IoT applications are critical in nature. This motivates to provide QoS across multiple dimensions [21]. Network and resource providers of IoT application connect them carefully so that multiple computing applications can coexist in it. The environmental attributes like temperature and location, the characteristics of the network like latency, bandwidth, power, and battery life play a vital role in application's QoS. IoT applications need responsiveness and precision smart objects are active members of IoT to collaborate and to communicate with each other by interchanging information of sensed data and act as a self-ruling to the physical world. It creates the services with or without interacting with any person [21]. Different QoS models are required for different IoT applications to limit obligatory factors to satisfy the needs of those services.

WSN is a major component of the IoT, QoS provided by optimizing the resource utilization by joining multiple sensor nodes with the global Internet. This protocol provides the best quality of control in the applications of IoT [33].

6 Conclusion

This paper concludes that "IoT" is an emerging technology. The integration of embedded systems and the Internet paved the researchers in new directions and the technology was developed. Use of wireless sensors to create the mesh of network and send data or information over the Internet enhances the utility of IoT in every field. The general architecture of IoT is given in this paper and can vary from application to application. To enhance the interoperability between human, thing, and machine still lots of work are needed to be done on its quality of services, communication protocols, and standardized architecture of "Internet of Things."

Table 3 IoT applications and their properties

	Retail supply chain	Medical and health	Aid for aged and physically disabled person	Transport	Manufacturing	Automation
Network size	Small	Small	Small	Big	Medium	Medium
Users	Region based	Region based	Region based	Region based	Within industry	Within premises
Energy	Rechargeable	Rechargeable	Rechargeable	Rechargeable	Rechargeable	Rechargeable
Internet	Wi-Fi, GSM	Wi-Fi, GSM	Wi-Fi, GSM	Wi-Fi, GSM	Wi-Fi, GSM	Wi-Fi, GSM
Topology	Bus	Star	Star		Mesh	Bus
Data management	Local server	Shared server	Shared server	Global	Local	Local
IoT devices	RFID, WSN	WBSN	WBSN	RFID, WSN	RFID, WSN	RFID, WSN, WBSN
Bandwidth	Small	Medium	Medium	Large	Medium	Small

7 Future Scope

The architecture of IoT is still application dependent and, similarly, protocols of communication are medium specific [5]. Both areas still have lots of research scope for development in future. Another area is to develop the technologies to revocable pseudonymity. Anonymity addresses the global identity schemes, encryption/encoding, and repository authority with the help of recognition, authentication of parties, authentication, and addressing plan as well as building the discovery services and global directory lookup services. In the field of robotics, IoT should be used to design collaborative robots [34].

References

1. Maney, K.: Meet Kevin Ashton, Father of the Internet of Things (2015) (Online). http://www.newsweek.com/2015/03/06/meet-kevin-ashton-father-internet-things-308763.html. Accessed 21 Dec 2017
2. Ashton, K.: That ‘Internet of Things’ Thing—2009-06-22—Page 1. RFID J. (2009) (Online). http://www.rfidjournal.com/articles/view?4986. Accessed 14 Dec 2017
3. Ibarra-Esquer, J.E., González-Navarro, F.F., Flores-Rios, B.L., Burtseva, L., Astorga-Vargas, M.A.: Tracking the evolution of the internet of things concept across different application domains. Sensors **17**(6), 1379 (2017)
4. Adibi, S.: Mobile Health: A Technology road Map. Springer, Cham (2015)
5. Said, O., Masud, M.: Towards Internet of Things: survey and future vision. Omar Said Mehedi Masud Int. J. Comput. Netw. **5**(1), 1 (2013)
6. Atzori, L., Iera, A., Morabito, G.: The Internet of Things: A survey. Comput. Netw. **54**(15), 2787–2805 (2010)
7. Welbourne, E., et al.: Building the Internet of Things using RFID. IEEE Internet Comput. **13**(3), 48–55 (2009)
8. Kortuem, G., Kawsar, F., Sundramoorthy, V., Fitton, D.: Smart objects as building blocks for the Internet of things. IEEE Internet Comput. **14**(1), 44–51 (2010)
9. Buratti, C., Conti, A., Dardari, D., Verdone, R.: An overview on wireless sensor networks technology and evolution. Sensors **9**(9), 6869–6896 (2009)
10. Sundmaeker, H., Guillemin, P., Friess, P., Woelfflé, S.: Vision and challenges for realising the Internet of Things. The meaning of things lies not in the things themselves, but in our attitude towards them. Antoine de Saint-Exupéry (2010)
11. O’Neill, S.: Generalized Hyperalgesia in Chronic Low-Back Pain. River Publishers (2013)
12. Ray, P.P.: A survey on Internet of Things architectures. J. King Saud Univ. Comput. Inf. Sci. (2016)
13. Fortino, G., Russo, W., Savaglio, C., Viroli, M., Zhou, M.: Modeling opportunistic IoT services in open IoT ecosystems. Comput. Sci. Eng. **19**(5), 68–76 (2017)
14. Celandroni, N., et al.: A survey of architectures and scenarios in satellite-based wireless sensor networks: system design aspects. Int. J. Satell. Commun. Netw. **31**(1), 1–38 (2013)
15. Bandyopadhyay, D., Sen, J.: Internet of Things: applications and challenges in technology and standardization. Wirel. Pers. Commun. **58**(1), 49–69 (2011)
16. Zurich Tian, E.H.: Energy-efficient features of Internet of Things protocols (2018)
17. Gubbi, J., Buyya, R., Marusic, S., Palaniswami, M.: Internet of Things (IoT): a vision, architectural elements, and future directions. Future Gener. Comput. Syst. **29**(7), 1645–1660 (2013)
18. Chowdhury, M.N., Bhuiyan, M.M.H., Islam, S.: IOT: detection of keys, controlling machines and wireless sensing via mesh networking through internet. Glob. J. Res. Eng. (2013)

19. Karl, H., Willig, A.: Protocols and Architectures for Wireless Sensor Networks. Wiley (2005)
20. Hersent, O., Boswarthick, D., Elloumi, O.: The Internet of Things: Key Applications and Protocols. Wiley InterScience (Online service), Wiley (2012)
21. Nef, M., Perlepes, L., Stamoulis, G.I.: Enabling QoS in the Internet of Things. In: CTRQ 2012 : The Fifth International Conference on Communication Theory, Reliability, and Quality of Service, no. c, pp. 33–38 (2012)
22. Madakam, S., Ramaswamy, R., Tripathi, S.: Internet of Things (IoT): a literature review. J. Comput. Commun. **3**(3), 164–173 (2015)
23. Watt, J.H., Lynch, M.: Using the Internet for audience and customer research. In: IPCC 99. Communication Jazz: Improvising the New International Communication Culture. Proceedings 1999 IEEE International Professional Communication Conference (Cat. No. 99CH37023), pp. 121–130
24. Sole, M., Musu, C., Boi, F., Giusto, D., Popescu, V.: RFID sensor network for workplace safety management. In: 2013 IEEE 18th Conference on Emerging Technologies & Factory Automation (ETFA), pp. 1–4 (2013)
25. Miorandi, D., Sicari, S., De Pellegrini, F., Chlamtac, I.: Internet of Things: vision, applications and research challenges. Ad Hoc Netw. **10**(7), 1497–1516 (2012)
26. Darwish, A., Hassanien, A.E.: Wearable and implantable wireless sensor network solutions for healthcare monitoring. Sensors **11**(6), 5561–5595 (2011)
27. Kerner, S.M.: The Internet of Things thread network protocol debuts (2014) (Online). http://www.enterprisenetworkingplanet.com/netsp/the-internet-of-things-thread-network-protocol-debuts.html. Accessed 15 July 2014
28. Gravina, R., et al.: Enabling multiple BSN applications using the SPINE framework. In: 2010 International Conference on Body Sensor Networks (BSN), pp. 228–233. IEEE (2010)
29. Atallah, L., Lo, B., Yang, G.-Z., Siegemund, F.: Wirelessly accessible sensor populations (WASP) for elderly care monitoring. In: *2008 Second International Conference on Pervasive Computing Technologies for Healthcare*, pp. 2–7 (2008)
30. Jacobsson, A., Boldt, M., Carlsson, B.: A risk analysis of a smart home automation system. Future Gener. Comput. Syst. **56**, 719–733 (2016)
31. Ghasemzadeh, H., Fallahzadeh, R., Jafari, R.: A hardware-assisted energy-efficient processing model for activity recognition using wearables. ACM Trans. Des. Autom. Electron. Syst. **21**(4), 1–27 (2016)
32. Koop, C.E., et al.: Future delivery of health care: Cybercare. IEEE Eng. Med. Biol. Mag. **27**(6), 29–38 (2008)
33. Cao, H., Leung, V., Chow, C., Chan, H.: Enabling technologies for wireless body area networks: a survey and outlook. IEEE Commun. Mag. **47**(12), 84–93 (2009)
34. Industrial Internet of Things: Cobots and Connectivity (Online). http://www.roboglobal.com/industrial-internet-of-things-cobots-and-connectivity. Accessed 19 Dec 2017
35. A roadmap for the Internet of Things|Internet of objects (Online). https://internetofobjects.wordpress.com/2011/03/31/a-roadmap-for-the-internet-of-things/. Accessed 19 Dec 2017
36. Digital Lifestyle Malaysia—Internet of Things—overview (Online). http://dlm.skmm.gov.my/Internet-of-Things/Overview.aspx. Accessed 19 Dec 2017