A Social-D2D Architecture for People-centric Industrial Internet of Things

Lin Yang, Wenfeng Li, Yun Luo, and Ying Duan
School of Logistics Engineering
Wuhan University of Technology
Wuhan, China
{lyang, liwf, yluo, yduan}@whut.edu.cn

Giancarlo Fortino
DIMES
University of Calabria
Rende, Italy
g.fortino@unical.it

***Abstract*— The widespread deployment of smart phone and smart object technologies have fostered the rise of People-centric Internet of Things. People-centric Internet of Things is the direct motivation and drive for agile and social manufacturing applications in future Industry 4.0. However, it is challenging for human to organize services around with crowdsourced, open, decentralized smart objects. In this paper, we propose a service-oriented architecture for People-centric Industrial Internet of Things, and define a reference middleware for both smart phone and smart objects. In addition, a social activities component and a physical activities component of the middleware are presented to trigger interoperations among services, and contain several features of natural intention between humans. Finally, a use case is illustrated how the proposed architecture supports people-centric manufacturing applications.**

***Keywords*— People-centric Industrial Internet of Things; Smart object; Smart phone; Device-to-Device Interaction ; Industry 4.0**

I. Introduction

The number of Internet of Things (IoT) devices will rapidly grow up over 50 billion in 2020[1]. The evolution of Internet of IoT technology over the past few years has brought us to resource-crowding environment. The IoT environment fully fill with the mobility, complexity and heterogeneity of densely-deployed wireless devices and services [2]. Smartphone and personal individual devices, i.e., bicycles, vehicles driven by people, are natural tools for interact with them [3-5], and current IoT is shifting to People-centric Internet of Things (PIoT) along with challenges [6].

Several changes are needed in current architecture for new PIoT service interaction paradigm. In the IoT vision [7], people's daily activities capabilities are supported by a global network of interconnected services and smart objects. People consume information through personal devices connected to a specific cloud platform, as an observer. A decade ago, research prototype smart phone-based interaction began to emerge [8], facilitating the genesis of People-centric sensing as they exist today: people aggregate and share data with people spatial-temporal behavior, as sensing node of IoT. Social smart objects build a social network of things [9], and people interact with smart object in the physical world to connect two social networks, as social beings. Finally, people interactions become essential of IoT, but not things. So, PIoT goes beyond things oriented IoT, and is considered to improve current thing-to-thing and human-to-thing interactions.

However, current IoT architecture is designed to support vertical solution for accessing physical-word information and services, and the services and information are based on closed specific application, or specific platform [9]. When situation of people surroundings is changed, people's personal device is required to manually fix it by client-server interaction model, i.e., by installing new APPs, registry for new service, or empower from cloud server etc. The past regarding IoT architecture is lack dynamic configurable integration, natural interaction, and proactive and anticipate people needs. Moreover, these features are crucial elements for PIoT. So, an open and smart PIoT service architecture is required to support seamlessly human-machine interactions everywhere.

The motivations and principles of the architecture design in this work is as following:

- Dynamic integration. PIoT environment cannot change overnight, and seeks for a smooth migration path from existing deployment to emerging future social smart objects. Currently, it is not only pervasive mobile smart objects with dynamic self-organized services, but also facing the existing fixed specifically-domain services. How to exchange services among heterogeneously service entities without manually reconfiguration? A common service model is required for supporting spatial-temporal services in PIoT environment.
- Decentralized communication. People opportunistic needs are satisfied by services from smart object nearby, and services are made of one individual smart object, or federations of smart objects. How to freely combine/depart a service network should be considered. Classical Peer-to-Peer (P2P) network architecture provides a scalable solution [10], and smart objects can be dynamical integrated in this kind of open and smart IoT platform. However, a node is limited to know large-scale connection relationship among neighbor nodes. So, a regular cloud servers, as nodes, should be considered in a new P2P-like PIoT architecture.
- Directly interaction. Smartphone is an interface for human and IoT ecosystem [11], and directly interaction is required for human natural interactions in physical

This work is supported in part by the NSFC (61571336) and the ISTCP (2015DFG12210).978-1- 5090-4429- 0/17/$31.00 ©2017 IEEE

word. Moreover, interactions among human and thing are highly frequency in crowdsourcing surroundings. However, the capabilities of computing and energy are limited. So, how to reduce the complexly of service aggregation is a key mission for PIoT architecture.

To address the needs above, this paper introduces a service-oriented PIoT architecture to support directly human-machine interactions. The paper is organized as follows. In section II, Related works on IoT architecture are briefly introduced. In section III, details of a PIoT architecture are discussed, in which social device-to-device (Social-D2D) interaction technology is emphasized. In section IV a people-centric service middleware model is depicted for Social-D2D interaction. In section V, we explain how to customize the proposed architecture in Industrial Internet of Things (IIoT) application. Finally, conclusions are drawn in Section VI.

II. RELATED WORK

A. Things-oriented Architecture for Single People-centric Aggregation

In past regarding IoT studies [9], a group of general reference architecture are design for vertical solutions, such as Auto-ID, IoT-A and Open IoT etc. Devices are connected to and shared out via a centralized cloud platform, and people interact with services in a closed ecosystem. The essential interactions of IoT are things-to-things, and take place in cloud web via M2M and web feed technologies. To make these architectures more people-centric, some research projects propose a people-centric sensing architectures for specific applications, such as [12,13] for people health, [8,14] for environment and [15] for emergency event. People carry with embedded devices to aggregate data and information around, and data and services are bundled in a cloud server. However, interactions in these systems are based on single people centric paradigm, services are consumed based on traditional operations (window, icon, menu, pointing device) style [16].

B. Semantic-oriented Architecture for People-centric Needs

To improve natural people-things operation, a set of studies on IoT go in the direction of more open to support social interoperation among things. Authors [17] compare the current middleware for smart object, and figures out the need of automatic configuration and self-* architecture for massively smart object-based IoT. Web of things and internet of all [19,20] propose architectures for proactive and anticipate capabilities, and heterogeneous things are virtualized via the unified protocols, plus the virtual resources are mashup to fulfill peoples' needs in cyber world. Peoples' status is perceived and inferred by "things" around, including emotions, activities, psychological information. In these semantic oriented architectures, things are ubiquitous and distributed, and things be connected in communities, moreover, collaborations are subjected to different ruled policy and specific tasks. The Social Internet of Things (SIoT) [21] is a network for social interaction between intelligent objects. The authors propose a three-layer model, including the sensing, network, and application layers. Specifically, the application layer combines service, social and applications components sited in each physical thing, i.e., smart gateway, objects. The services organize a set of things with relationship, but reducing complexity should be considered in this solution, especially in people-things directly interaction using capabilities limited devices.

C. Service-oriented Architecture for People-centric Interaction

Due to the huge number of smart objects with m-service [16] (mobile, micro, and management services in smart environment) in PIoT, several studies focus on services interaction model to reduce complexity and increase human feature of IoT environment. On one hand, people take advantage of smart phone as a human-IoT interface to select minimum resources. Author [3] proposed a high-level architecture for mobile phone integrated into IoT, and an internet of people middleware is presented to support a service-oriented system, moreover, the people-as-services middleware contains devices registry, people roles of repository, actions, applications. SmartCitizen app [22] develops on top of a context- and social-aware middleware platform named CAMEO, and the middleware is added in PIoT architecture for supporting a large-scale people centric services, and intends to be a common middleware for mobile phones and mobile social networks in urban applications. On the other hand, a thing is self-organized and managed like human social to increase intelligence. For cooperation among smart object, authors in [18] present a cloud-assisted and agent-oriented IoT architecture for decentralized smart objects, and an agent-oriented middleware for cooperating smart objects, and BodyCloud, a sensor-cloud infrastructure for large-scale sensor-based systems. Open Things [23] proposes a distributed platform take advantage of spatial-temporal context, to facilitate the integration of semantic technologies into IoT environments, and the platform defines ontologies to describe knowledge about time and space entities (device services, virtual services, virtual environment and applications), moreover, entities are used to make rules to implement and define proactive behaviors carried meaning to people. To fulfill the gap of two sides, there is improvement room for people-centric architecture to add more features, i.e., social, spatial-temporal, activities, event triggers etc., in both smart phone and smart objects with a unified way.

III. PEOPLE-CENTRIC IOT FRAMEWORK

Figure 1 shows a high-level tiered architecture, and is conceived as a people-centric interaction ecosystem with various components: P2P physical resource layer, distributed services D2D interaction layer, and Socialcial-D2D enhanced graph layer.

A. P2P Physical Resources Layer

Physical resource layer contains distributed infrastructure and real-word conditions around people, such as smart devices, smart phones, regular servers in cloud, wireless network communications, people health status, weather environment, manufacturing event and meetings, etc. The resources are mixed with individual elements defined by smart objects, and the unified smart objects is used to aware itself and surroundings around. The communication in the resources is based on P2P model, and a smart object is only required to maintain connections of limited number of adjacent smart objects. To model the physical human-machine interaction, the segmentations of smart object environment are defined into three mainly nodes as following:

- people node, is considered as a special smart object with a set of wireless body sensors and smart phone. And smart phone is a physical interface tool for people to interact with IoT devices, and aggregates services and preference data on demand, to reduce complexly of resources.
- local smart object node, refers to data sources and smart devices with capability of sensing, communication, computing, and self-services, and it will be the mainly resources in future IoT physical word. Local smart object can be self-organized to build a specific service for people needs, via individual or a set of them. Moreover, each of the smart object node has unified components structure and is abstracted to support a m-service model, to directly operated by people.
- Cloud assistant node, refers to current regular servers running on internet. On one hand, it bridges wired and unintelligent measuring devices to IoT environment, and virtualized and reorganized the devices data in backend server running as a standard smart object. On the other hand, due to super capabilities of computing, storage, and bandwidth, cloud server node provides specific service for coordinating some distributed m-service software in privacy, security, social relationship management, etc., but not a global centralized server. Moreover, a cloud servers are still used as smart objects running standard functional structure in the P2P ecosystem.

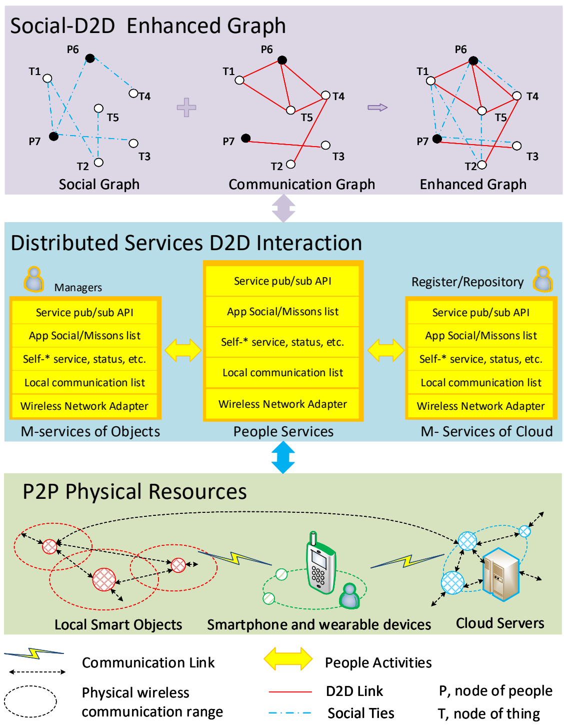

Figure.1. People-centric IoT architecture

B. *Distributed Service D2D Interaction Layer*

This layer is a software layer with entities unified D2D interaction middleware, and a middleware software entity is mapped into and relied on a proposed physical smart object nodes. D2D middleware is driven by a people-centric model, to interoperate services resources among people node, local smart objects node and cloud server nodes, and hides various technical interaction details of heterogeneous physical devices.

C. *Social-D2D Enhanced Graph Layer*

Social-D2D graph is aim to describe cooperation among people and things in PIoT, and m-service with the middleware is abstracted a node of this enhanced graph. Plus, the graph data storage is distributed in each physical smart object. Social graph is built on not only the online social network relationship of people activities, but also connections of implicit dependencies, e.g., a certain group of people roles and skills, field devices in a factory, process and product data in manufacturing.

Moreover, it is a promising alternative for exchanging high frequently interaction contents on-the-go. On one hand, people as a joint node to connect graph of human social networks and D2D communications, and actions of people enhance the connectivity of whole m-services and physical smart objects environment. On the other hand, a sub-graph is utilized to representation a set of m-service for a specific application or a mission, and a mission is finished by exchanging sub-graph service list between people, like URI. All the data and information exchange is carried out among individual smart objects on the list. By the idea, service and data are available on local smart objects, just visited directly without through central network.

IV. People-centric Service Model

A. *People-centric Service Middleware*

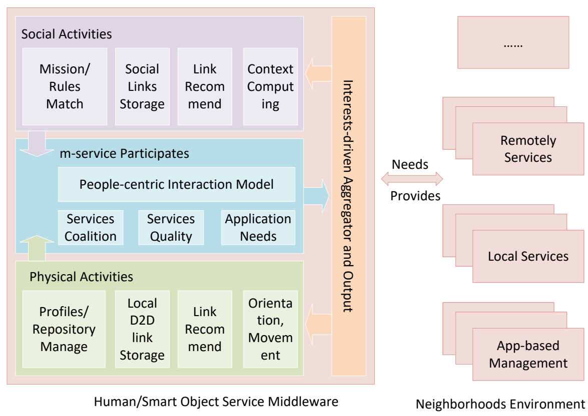

Fig.2 People-centric service middleware

As shown in figure 2, a middleware is consisted by several components including: m-service participates, social and physical actives, interest-driving aggregator and output.

- m-service participates component receives a set of service request needs from neighbor environment, and identify, select, and mash-up services by merging into a service coalition. And the service coalition exposes as a link table of services to satisfied neighbor needs. A link table is a service reference by several other services. In addition, to satisfy needs from outside, an output of m-service can be a set of related services conference table, and creates a new cooperation request needs to other smart objects. It may be named an output services coalition.

- Social activities component is defined to dynamically processing the social relationship of services resource pool, and designed to recommend a right action according to inherent rule and mission schedules, such as assembling procedure in cyber manufacturing, filed devices service sharing and renting relationship, customer management in trading, etc. Moreover, the component provides real time social status for m-service as its needs or interests.
- Physical activities component is defined to interact or cooperate with other smart objects. It records the current connects of neighbors, and is used to recommend the optimal one according to cost, energy consumption, identify the physical routing by repository, profile parameters, such as orientation, movement etc. It would be described a filed device's interoperation in a workshop loop. The physical preference of m-service is from the component.
- Interest-driven aggregator/output component is defined to collect service link table relying on the m-service needs and interests. And it disseminates packages of service link table and information on demand.

B. Human Features for Services Interaction Model

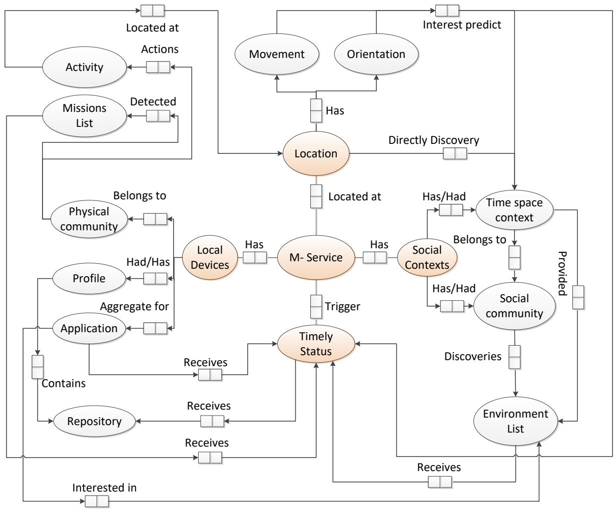

Figure. 2. People-centric m-Service model

To make the smart objects more human centeredness, an interaction model is illustrated to unified smart object software service. Eight common properties are considered to model the service context in human-machine interaction, including identity, distance, orientation, movement, location, time, environment and items for proxemics interface [13,16]. In this paper, four critical elementals are used as key features to model an individual m-service shown in figure 2, including location, time, social connection, local devices connection, and others are used for defining action triggers. Moreover, the triggers actives the actions of m-service, such as movement, orientation and environment. These parameters for interactions are used to understand human centeredness context of personalization (interest, preferences, activates) and participation features.

C. Service Metrics

User satisfaction degree and service changing cost have been considered to evaluate a service, in perspective of user consuming [24]. Comparing with a global satisfaction degree calculated on center server, our proposed people-centric service model evaluation is prospect of calculation the service quality for visited ones (consumer and provider) in local or partly services network. Moreover, considering the human trust in social-d2d graph, a service ranking-based selection and incentive constraints are motivation of service changing from one to another. For a user, a service satisfaction can be defined by satisfaction procedure from an input action of request/query to an output action of service provider. The service can be evaluated by an equation as following.

$$\Phi_0 = \sum_{i=1}^{n}(N_i D_i) \Big/ \sum_{i=1}^{n}(W_i C_i)$$

Where Φ_0 is noted as a service evaluation of a smart object. A service request is received by a smart object, and it is satisfied with a set of related services, including the number of services n, and N_i is defined a specific service which the smart object i can be served. D_i is denoted as a satisfaction degree, and the current single smart object can provide a percentage service in its service coalition. C_i is the cost of the service including reaction time, energy consumption, the length of routing path, quality etc. And W_i is participant rate with weight coefficient in its service coalition, $W_i \in [0,1]$. While $W_i = 0$, the smart object does not contribute service, just relay needs information. and while $W_i = 1$, the smart object provides the service alone without service coalition. Note that, the service cost maybe always increasing in a global service flow [24], but in our proposed interaction model, a social context and directly service interaction mechanism can always provide a solution via cyber space.

V. AN INDUSTRY 4.0 USE CASE

A. People-centric Manufacturing Scenario

To win competitions on manufacturing markets, needs of advanced manufacturing are shifting from large-scale integration to a small batch, customized, and crowdsourced cooperation, to timely response the dynamical markets changes. And the needs drive developments of manufacturing paradigm of flexibility manufacturing, agile manufacturing, cyber manufacturing [25] and social manufacturing [26]. Moreover, the manufacturing trends speed implements of IIoT and Cyber Physical System technologies, and was paved to Industry 4.0. The Industry 4.0 scenarios, human, field devices, product and other manufacturing resource, as service resource, can be shared on whole manufacturing lifecycle and value chain. People are both service consumers and providers, and smart objects' services in manufacturing are organized in a way to people-centric.

Under the briefly background of people-centric manufacturing, an artificial example of car wheel manufacturing is illustrated with smart object resources shown in figure 4. In our case, a wheel should be modified during manufacturing stage, while a wheel sample in selling store receives a customer specific need to milling personal logo. The focus is on the engraving of Computer Numeric Control (CNC) machine, and it is a subsequent process of production the individual parts before assembling. First, a material plate is engraved and checked by worker's smartphone, before in a coming step of assembling. These procedures take place in production line1 and line2, and human workpiece carrier transmit information via mobility. In addition, humans and machines interoperate in pairs. The CNC machine and wheels are equipped with a m-service in an embedded device, and the service represents all product-specific data and social-D2D information in whole lifecycle. Second, wheel samples have smart tracking services in the shelf stands at shopping mall, and track a customer's smartphone and analysis out the his/her favor wheel. A selected sample is customized by customer. Third, the wheel sample disseminates the customer needs to social graph of cyber manufacturing, and launches production task changes in production schedules via a set of machine services. The next step, products-machines social graph provides relevant machines in wheel's repository of production, and then notification workers and specific field machine via D2D machine-materials pairs. Thus, the CNC machine assignment changes can be registered early in the process flow, without changing the planned production schedules of other machines, and the matching and decision making are occurred in social-D2D graph of m-service.

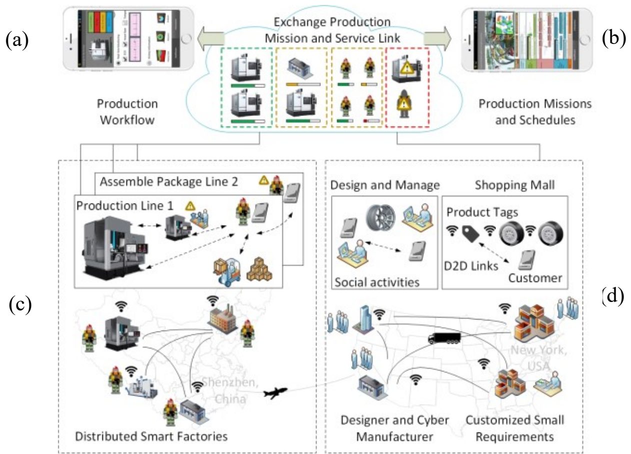

Fig.4 A real-time customer participation manufacturing mechanism is illustrated.

B. *Scenario-based Implement of PIoT Architecture*

The proposed people-centric architecture supports a customized manufacturing procedure, and a PIoT architecture for the scenario is described as following. At human level, smart phone provides a service of tracking people interests and preference, and aggregating service from surroundings. Smart phone as a tool to interact with machines in smart workshop or products at shopping mall. Workers enable to read field manufacturing information and control the machine working status via mobile devices shown in figure 4(a), Customers preference and customized manufacturing task can be tacked and collected via mobile devices shown in figure 4(b). At cyber factory and enterprise level, a CNC machine is added an embedded computer and exposes its production service and assignment information shown in figure 4(c), and directly connects other field devices and smartphones in physical and cyber space. In addition, the distributed machines are organized in cyber logical workshops or factories via business needs and manufacturing task. At global market level, design, manufacturing business, customers-providers' social activities as a service run in cloud servers, and create production missions and manufacturing schedules shown in figure 4(d).

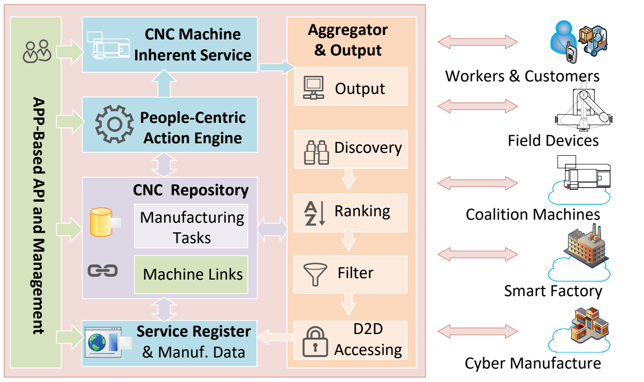

Fig.5 A CNC machine middleware

C. *People-centric IoT Middleware for Field Devices*

In our case, a CNC machine is one of mainly tools to production car wheels, and interacts with workers, coalition machines, cyber manufacturer owners, etc. It is selected as an example to implement PIoT middleware shown in figure 5. The component of Aggregator and Output is used to carry out D2D services interaction devices at workshop and in cloud, such as detecting service of aluminum materials supply services, robots arm cooperation services, service of conveyor carrier and forklifts with drivers.

CNC Repository component inputs manufacturing rules and processing task needs to Aggregator & Output component, moreover it is used to provide constraints and criteria parameters for filtering and ranking services. Repository recodes social graph of wheel production knowledges, local D2D device pair links, and dynamical human or other machine operation dictionary.

Service Register component can be defined to sub/pub field environment data from inherent services, or receive production command from filtered machines or smart phones, and modifies its repository itself or updates its visited records to coalition machines.

People-centric Action Engine component is used to process the incoming status of repository, and makes out action instructions under the rule of human feature interaction model. In addition, the instructions of action are carried out by closed control loop inner CNC machine or open control loop at workshop level with coalition field devices and workers.

APP-based Management component is used to self-reconfiguration the connection graph of a CNC machine itself, and coordinates field devices work flow and build social relationship with repository. It also is utilized as an open API layer, to expose internet service directly for emergency interruption, such as personal customized assignment, an accident, owner changing in business activities.

VI. CONCLUSION

Mobile phone and low-cost IP-enabled embedded hardware with light server are widely used in physical industrial domain, and makes devices, machines and humans exposed services in a people-centric way. Current reported IoT architecture is based on closed vertical and specific cloud-centric solution, and human interaction and proactive of IoT environment are limited in a platform-based or application-specified system. This paper proposed a possible method for a people-centric IoT architecture with decentralized self-organized smart objects, device-to-device service interaction among human and smart objects. The possible approach to implement of the service-oriented PIoT concept is briefly described. Based on the social-D2D graph and middleware technologies, we define a service framework for both smart phone and smart objects with three components, including social activities, physical activities, and people-centric action-driven m-server. The proposed framework provides human features in services interactions among human and IoT resources. A use case of personal car wheel customized manufacturing is present to illustrate what the concept will be implemented in Industry 4.0. From the scenario, several features of proposed people-centric service model can be summarized as following: (a)the services can be run in any devices, not rely on expensive server or hardware. (b) services interaction among smart object is implicit without human intervention. (c) the dissemination of service request information between customer and works are routed in both social and physical connection graph. For the social-D2D graph, a clear mechanism of human needs dissemination should be considered in future work.

REFERENCES

[1] Jun, Zhang, D. Simplot-Ryl, C. Bisdikian, and H. T. Mouftah. "The internet of things." IEEE Commun. Mag 49, no. 11 (2011): 30-31.

[2] Gubbi, Jayavardhana, Rajkumar Buyya, Slaven Marusic, and Marimuthu Palaniswami. "Internet of Things (IoT): A vision, architectural elements, and future directions." Future Generation Computer Systems 29, no. 7 (2013): 1645-1660.

[3] Miranda, Javier, Niko Mäkitalo, Jose Garcia-Alonso, Javier Berrocal, Tommi Mikkonen, Carlos Canal, and Juan M. Murillo. "From the Internet of Things to the Internet of People." IEEE Internet Computing 19, no. 2 (2015): 40-47.

[4] Vegni, Anna Maria, and Valeria Loscri. "A survey on vehicular social networks." IEEE Communications Surveys & Tutorials 17, no. 4 (2015): 2397-2419.

[5] Aloi, Gianluca, Marco Di Felice, Valeria Loscrì, Pasquale Pace, and Giuseppe Ruggeri. "Spontaneous smartphone networks as a user-centric solution for the future internet." IEEE Communications Magazine 52, no. 12 (2014): 26-33.

[6] Boavida, Fernando, Andreas Kliem, Thomas Renner, Jukka Riekki, Christophe Jouvray, Michal Jacovi, Stepan Ivanov, Fiorella Guadagni, Paulo Gil, and Alicia Triviño. "People-Centric Internet of Things—Challenges, Approach, and Enabling Technologies." In Intelligent Distributed Computing IX, pp. 463-474. Springer International Publishing, 2016.

[7] Ortiz, Antonio M., Dina Hussein, Soochang Park, Son N. Han, and Noel Crespi. "The cluster between internet of things and social networks: Review and research challenges." IEEE Internet of Things Journal 1, no. 3 (2014): 206-215.

[8] Campbell, Andrew T., Shane B. Eisenman, Nicholas D. Lane, Emiliano Miluzzo, Ronald A. Peterson, Hong Lu, Xiao Zheng, Mirco Musolesi, Kristóf Fodor, and Gahng-Seop Ahn. "The rise of people-centric sensing." IEEE Internet Computing 12, no. 4 (2008): 12-21.

[9] Atzori, Luigi, Antonio Iera, and Giacomo Morabito. "From" smart objects" to" social objects": The next evolutionary step of the internet of things." IEEE Communications Magazine 52, no. 1 (2014): 97-105.

[10] Dressler, Falko. "A study of self-organization mechanisms in ad hoc and sensor networks." Computer Communications 31, no. 13 (2008): 3018-3029.

[11] Aloi, G., G. Caliciuri, G. Fortino, R. Gravina, P. Pace, W. Russo, and C. Savaglio. "Enabling IoT interoperability through opportunistic smartphone-based mobile gateways." Journal of Network and Computer Applications (2016).

[12] Lane, Nicholas D., Mu Lin, Mashfiqui Mohammod, Xiaochao Yang, Hong Lu, Giuseppe Cardone, Shahid Ali et al. "Bewell: Sensing sleep, physical activities and social interactions to promote wellbeing." Mobile Networks and Applications 19, no. 3 (2014): 345-359.

[13] Yang, Lin, Wenfeng Li, Yanhong Ge, Xiuwen Fu, Raffaele Gravina, and Giancarlo Fortino. "People-Centric Service for mHealth of Wheelchair Users in Smart Cities." In Internet of Things Based on Smart Objects, pp. 163-179. Springer International Publishing, 2014.

[14] Kim, Hyunsoo, Changbum R. Ahn, and Kanghyeok Yang. "A people-centric sensing approach to detecting sidewalk defects." Advanced Engineering Informatics 30, no. 4 (2016): 660-671.

[15] Ochoa, Sergio F., and Rodrigo Santos. "Human-centric wireless sensor networks to improve information availability during urban search and rescue activities." Information Fusion 22 (2015): 71-84.

[16] Volpentesta, Antonio P. "A framework for human interaction with mobiquitous services in a smart environment." Computers in Human Behavior 50 (2015): 177-185.

[17] Fortino, Giancarlo, Antonio Guerrieri, Wilma Russo, and Claudio Savaglio. "Towards a Development Methodology for Smart Object-Oriented IoT Systems: A Metamodel Approach." In Systems, Man, and Cybernetics (SMC), 2015 IEEE International Conference on, pp. 1297-1302.

[18] Fortino, Giancarlo, Antonio Guerrieri, Wilma Russo, and Claudio Savaglio. "Integration of agent-based and Cloud Computing for the smart objects-oriented IoT." In Computer Supported Cooperative Work in Design (CSCWD), Proceedings of the 2014 IEEE 18th International Conference on, pp. 493-498. IEEE, 2014.

[19] Nunes, David Sousa, Pei Zhang, and Jorge Sá Silva. "A survey on human-in-the-loop applications towards an internet of all." IEEE Communications Surveys & Tutorials 17, no. 2 (2015): 944-965.

[20] Zhang, Ningyu, Huajun Chen, Xi Chen, and Jiaoyan Chen. "Semantic Framework of Internet of Things for Smart Cities: Case Studies." Sensors 16, no. 9 (2016): 1501.

[21] Atzori, Luigi, Antonio Iera, Giacomo Morabito, and Michele Nitti. "The social internet of things (siot)–when social networks meet the internet of things: Concept, architecture and network characterization." Computer Networks 56, no. 16 (2012): 3594-3608.

[22] Delmastro, Franca, Valerio Arnaboldi, and Marco Conti. "People-centric computing and communications in smart cities." IEEE Communications Magazine 54, no. 7 (2016): 122-128.

[23] Calderon, Marco A., Saul E. Delgadillo, and J. Antonio Garcia-Macias. "A More Human-centric Internet of Things with Temporal and Spatial Context." Procedia Computer Science 83 (2016): 553-559.

[24] Zhu, Yishui, Roman Y. Shtykh, and Qun Jin. "A human-centric framework for context-aware flowable services in cloud computing environments." Information Sciences 257 (2014): 231-247.

[25] Lee, Jay, Behrad Bagheri, and Chao Jin. "Introduction to cyber manufacturing." Manufacturing Letters 8 (2016): 11-15.

[26] Jiang, Pingyu, Kai Ding, and Jiewu Leng. "Towards a cyber-physical-social-connected and service-oriented manufacturing paradigm: Social Manufacturing." Manufacturing Letters 7 (2016): 15-21